INTERNATIONAL STANDARD

ISO 10077-2

Third edition
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Thermal performance of windows, doors and shutters — Calculation of thermal transmittance —

Part 2:
Numerical method for frames

Performance thermique des fenêtres, portes et fermetures — Calcul du coefficient de transmission thermique —

Partie 2: Méthode numérique pour les encadrements

Reference number
ISO 10077-2:2017(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

ISO 10077-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 89*, Thermal performance of buildings and building components*, in collaboration with ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 10077-2:2012), which has been technically revised to comply with the requirements for the EPB set of standards. It also incorporates the Technical Corrigendum ISO 10077-2:2012/Cor 1:2012.

In addition, Clause 6 has been technically revised by

— adding a new approach for the treatment of cavities,

— separating conduction/convection and radiation, and

— introducing the radiosity method.

Annex H and Annex G were also added.

A list of all parts in the ISO 10077 series can be found on the ISO website.

Introduction

This document is part of a series aimed at the international harmonization of the methodology for assessing the energy performance of buildings. Throughout, this series is referred to as a "set of EPB standards".

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of this document, a normative template is given in Annex A to specify these choices. Informative default choices are provided in Annex B.

The main target groups for this document are architects, engineers and regulators.

Use by or for regulators: In case ISO 52000-1 is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs, but in any case following the template of this Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

NOTE 1 So in this case:

— the regulators will **specify** the choices;

— the individual user will apply the document to assess the energy performance of a building, and thereby **use** the choices made by the regulators

Topics addressed in this document can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B of this document. Public regulation on the same topics can even, for certain applications, override the use of this document. Legal requirements and choices are in general not published in standards but in legal documents. In order to avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that:

— national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case a national annex (e.g. NA) is recommended, containing a reference to these data sheets;;

— or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template of Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the Technical Report (ISO/TR 52022-2) accompanying this document.

The framework for overall EPB includes:

a) common terms, definitions and symbols;

b) building and assessment boundaries;

c) building partitioning into space categories;

d) methodology for calculating the EPB (formulae on energy used, delivered, produced and/or exported at the building site and nearby);

e) a set of overall formulae and input-output relations, linking the various elements relevant for the assessment of the overall EPB;

f) general requirements for EPB dealing with partial calculations;

g) rules for the combination of different spaces into zones;

h) performance indicators;

i) methodology for measured energy performance assessment.

ISO 10077 consists of two parts. This document is intended to provide calculated values of the thermal characteristics of frame profiles, suitable for use as input data in the calculation method of the thermal transmittance of windows, doors and shutters given in ISO 10077-1. It is an alternative to the hot box test method specified in EN 12412–2. In some cases, the hot box method can be preferred, especially if physical and geometrical data are not available or if the profile is of complicated geometrical shape.

Although the method in this document basically applies to vertical frame profiles, it is an acceptable approximation for horizontal frame profiles (e.g. sill and head sections) and for products used in sloped positions (e.g. roof windows). For calculations made with the glazing units in place, the heat flow pattern and the temperature field within the frame are useful by-products of this calculation.

The ISO 10077 series does not cover building facades and curtain walling, which are covered in ISO 12631.

Table 1 shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

NOTE 2 In ISO/TR 52000-2, the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation.

NOTE 3 The modules represent EPB standards, although one EPB standard could cover more than one module and one module could be covered by more than one EPB standard, for instance, a simplified and a detailed method respectively.

Table 1 — Position of this document (*in casu* M2–5), within the modular structure of the set of EPB standards

	Overarching		**Building (as such)**		**Technical building systems**										
Sub mo dule	**Descrip tions**		**Descrip tions**		**Descrip tions**	**Hea ting**	**Coo ling**	**Ven tila tion**	**Hu mi difi ca tion**	**De hu mi difi ca tion**	**Do mes tic hot wat er**	**Ligh ting**	**Buil ding auto ma tion and cont rol**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
1	General		General		General									
2	Common terms and definitions, symbols, units and subscripts		Building energy needs		Needs								a	
3	Applications		(Free) Indoor conditions without systems		Maximum load and power									
4	Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									
5	Building categories and building boundaries		Heat transfer by transmis-sion	ISO 10077-2	Emission and control									
6	Building occupancy operating conditions		Heat transfer by infiltra-tion and ventila-tion		Distribution and control									
7	Aggregation of energy ser-vices and energy carriers		Internal heat gains		Storage and control									
8	Building zoning		Solar heat gains		Generation and control									
9	Calculated energy performance		Building dynamics (thermal mass)		Load dispatching and operating conditions									

[a] The shaded modules are not applicable.

Table 1 *(continued)*

	Overarching		Building (as such)		Technical building systems									
Sub mo dule	Descrip tions		Descrip tions		Descrip tions	Hea ting	Coo ling	Ven tila tion	Hu mi difi ca tion	De hu mi difi ca tion	Do mes tic hot wat er	Ligh ting	Buil ding auto ma tion and cont rol	PV, wind, ..
sub1		M1		M2		M3	M4	M5	M6	M7	M8	M9	M10	M11
10	Measured energy performance		Measured energy performance		Measured energy performance									
11	Inspection		Inspection		Inspection									
12	Ways to express indoor com-fort				BMS									
13	External environment conditions													
14	Economic calculation													

[a] The shaded modules are not applicable.

Thermal performance of windows, doors and shutters — Calculation of thermal transmittance —

Part 2: Numerical method for frames

1 Scope

This document specifies a method and gives reference input data for the calculation of the thermal transmittance of frame profiles and of the linear thermal transmittance of their junction with glazing or opaque panels.

The method can also be used to evaluate the thermal resistance of shutter profiles and the thermal characteristics of roller shutter boxes and similar components (e.g. blinds).

This document also gives criteria for the validation of numerical methods used for the calculation.

This document does not include effects of solar radiation, heat transfer caused by air leakage or three-dimensional heat transfer such as pinpoint metallic connections. Thermal bridge effects between the frame and the building structure are not included.

NOTE Table 1 in the Introduction shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

2 Normative references

The following documents are referred to in text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7345, *Thermal insulation — Physical quantities and definitions*

ISO 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

ISO 10292, *Glass in building — Calculation of steady-state U values (thermal transmittance) of multiple glazing*

ISO 10456:2007, *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values*

ISO 12567-2:2005, *Thermal performance of windows and doors — Determination of thermal transmittance by hot box method — Part 2: Roof windows and other projecting windows*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 52000-1, *Energy performance of buildings — Overarching EPB assessment —– Part 1: General framework and procedures*

EN 673, *Glass in building — Calculation of thermal transmittance (U-value) — Calculation Method*

EN 12519, *Windows and pedestrian doors — Terminology*

NOTE Default references to EPB standards other than ISO 52000-1 are identified by the EPB module code number and given in Annex A (normative template in Table A.1) and Annex B (informative default choice in Table B.1).

EXAMPLE EPB module code number: M5–5, or M5–5.1 (if module M5–5 is subdivided), or M5–5/1 (if reference to a specific clause of the standard covering M5–5).

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, EN 12519, ISO 52000-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[10] and CEN/TS 16629[11]

Note 1 to entry: These three basic EPB documents were developed under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480), and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings (EPBD). Several EPB standards and related documents are developed or revised under the same mandate.

[SOURCE: ISO 52000-1:2017, definition 3.5.14]

4 Symbols and subscripts

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52000-1 and the following apply.

Symbol	Name of quantity	Unit
A	area	m^2
b	width, i.e. perpendicular to the direction of heat flow	m
d	depth, i.e. parallel to the direction of heat flow	m
C	constant in formula for Nusselt number	$W/(m^2 \cdot K^{4/3})$
E	intersurface emittance	—
F	view factor	—
h	heat transfer coefficient	$W/(m^2 \cdot K)$
L^{2D}	two-dimensional thermal conductance or thermal coupling coefficient	$W/(m \cdot K)$
l	length	m
Nu	Nusselt number	—
q	density of heat flow rate	W/m^2
R	thermal resistance	$m^2 \cdot K/W$
r	distance	m
T	thermodynamic temperature	K
U	thermal transmittance	$W/(m^2 \cdot K)$
σ	Stefan-Boltzmann constant	$W/(m^2 \cdot K^4)$

Symbol	Name of quantity	Unit
ε	emissivity	—
λ	thermal conductivity	W/(m·K)
Ψ	linear thermal transmittance	W/(m·K)
Θ	temperature	°C

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1 and the following apply.

Subscript	Description
c	convective (surface to surface)
e	external (outdoor)
g	glazing
eq	equivalent
f	frame
fr	frame adjacent to roller shutter box
i	internal (indoor)
rb	radiation black body
m	mean
p	panel
r	radiative
s	space (air or gas space)
sb	shutter box
se	external surface
si	internal surface

5 Calculation method

5.1 Output of the method

The possible outputs of this document are the following:

— thermal transmittance of a frame profile, U_f;

— thermal transmittance of a shutter box, U_sb;

— linear thermal transmittance of a junction of a frame profile with a glazing, Ψ_g or opaque panel, Ψ_p.

5.2 General principle

The calculation is carried out using a two-dimensional numerical method conforming to ISO 10211. The elements shall be divided such that any further division does not change the calculated result significantly. ISO 10211 gives criteria for judging whether sufficient sub-divisions have been used.

Two different approaches for the calculation of the heat transfer through cavities are given:

a) radiosity method;

b) single equivalent thermal conductivity method.

The radiosity method considers that the heat transfer through an air cavity occurs simultaneously through conduction/convection and through radiation. The two phenomena are happening in parallel so that the calculation of each contribution is done separately.

When using the single equivalent thermal conductivity method the heat flow rate in cavities is represented by a single equivalent thermal conductivity, λ_{eq}. This equivalent thermal conductivity includes the heat flow by conduction, by convection and by radiation, and depends on the geometry of the cavity and on the adjacent materials.

NOTE The single equivalent thermal conductivity method is equal to the calculation method given in ISO 10077-2:2012.

Vertical orientation of frame sections and air cavities is assumed for calculations by this document for the purposes of assigning equivalent thermal conductivity values (see 6.4.2.3.2 and 6.4.3.4.2). This applies irrespective of the intended orientation of the actual window, including roof windows.

Throughout this document, where indicated in the text, Table C.1 shall be used to identify alternative regional references in line with ISO Global Relevance Policy.

5.3 Validation of the calculation programs

To ensure the suitability of the calculation program used, calculations shall be carried out on the examples described in Annexes G and H (using the radiosity method) or Annex I (using the single equivalent thermal conductivity).

The requirements for all validation cases in Annexes G and H or Annex I shall be fulfilled.

The calculated two-dimensional thermal conductance L^{2D} for the cases in Annex H or Annex I shall not differ from the corresponding values given in Tables H.3 and H.4 or Tables I.3 and I.4 by more than ±3 %. This will lead to an accuracy of the thermal transmittance, U, and the linear thermal transmittance, Ψ, of about 5 %.

6 Calculation of thermal transmittance

6.1 Output data

The outputs of this document are transmission heat transfer coefficients as shown in Table 2.

Table 2 — Output data

Description	Symbol	Unit	Destination module	Validity interval	Varying
Thermal transmittance of frame profile	U_f	W/(m² K)	M2–5	>0... 20	No
Thermal transmittance of shutter box	U_{sb}	W/(m² K)	M2–5	>0... 20	No
Linear thermal transmittance	Ψ	W/(m K)	M2–5	–20... 20	No

6.2 Calculation time intervals

The calculations described in this document are steady-state and do not have time intervals.

6.3 Input data

6.3.1 Geometrical characteristics

Table 3 shows the necessary geometrical characteristics.

Table 3 — Identifiers for geometric characteristics

Description	Symbol	Unit	Range	Origin	Varying
Geometrical data					
Cross section of the frame profile				Manufacturer	No
Cross section of the shutter box				Manufacturer	No
Cross section of the junction frame profile and glazing				Manufacturer	No
Cross section of the junction frame profile and panel				Manufacturer	No

For frames with special extensions overlapping the wall or other building elements, such as Z-shaped profiles, the extensions shall be disregarded as illustrated in Figure 1. This applies to all profiles with special extensions (e.g. H-shape) where the extensions overlap the wall or other building elements. Other boundaries shall be treated as defined in Figure 4.

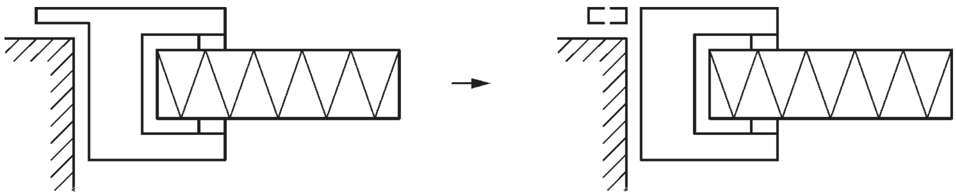


Figure 1 — Treatment of profiles with extensions (Z-shape)

NOTE 1 This approximation is for assessment of thermal transmittance. It is not appropriate for the assessment of condensation risk.

NOTE 2 The extension of the frame profile is disregarded in the calculation of the thermal transmittance of the window; see ISO 10077-1.

6.3.2 Thermal conductivity values

For the purpose of this document, thermal conductivity values used for solid materials shall be obtained according to one of the following:

— Table D.1;

— tabulated values given in ISO 10456;

— product standards;

— technical approvals by a recognized national body;

— measurements according to an appropriate International Standard.

Measurements shall be used only if there is no tabulated data or data according to relevant product standards or a technical approval. Measurements shall be performed at a mean temperature of 10 °C using the appropriate method by an institute accredited (as specified in ISO 17025) to carry out those measurements, on samples that have been conditioned at 23 °C and 50 % RH to constant mass (change in mass not more than 0,1 % over 24 h). To ensure that the thermal conductivity values are representative of the material (that is, that the value incorporates likely variability of the material and the measurement uncertainty), one of the following methods shall be used for obtaining the thermal conductivity value from measured data used in the calculations:

— the thermal conductivity is the declared value obtained from the measured data (at least three different samples from different lots representing the usual product variation, with ageing taken into consideration) according to a statistical evaluation as defined in ISO 10456:2007, Annex C, 90 % fractile;

— if less than three samples, use the mean value multiplied by a factor of 1,25.

6.3.3 Emissivity of surfaces

The surfaces bounding an air cavity shall have an emissivity of 0,9. Values less than 0,9 may be used only if taken from Table D.3 or measured in accordance with an appropriate standard by an institute accredited (as specified in ISO 17025) to carry out those measurements. Where based on measured values, there shall be at least three samples and the results shall be evaluated according to the statistical treatment in ISO 10456.

NOTE Metallic surfaces such as aluminium alloy frame, steel reinforcement and other metals/alloys have lower emissivity. Typical values of the emissivity for metallic surfaces are given in Table D.3.

6.3.4 General boundaries

The external and internal surface resistances depend on the convective and radiative heat transfer to the external and internal environments. If an external surface is not exposed to normal wind conditions, the convective part may be reduced in edges or junctions between two surfaces. The surface resistances for horizontal heat flow are given in Annex E. These values shall be used for calculations by this document irrespective of the intended orientation of the actual window, including roof windows. Surface condensation shall be assessed on the basis of the lowest internal surface temperature calculated using the surface resistances in Annex E.

The cutting plane of the infill and the cutting plane to neighbouring material shall be taken as adiabatic (see Figure 4 and Annex H).

The reference temperature conditions shall be 20 °C internal and 0 °C external.

6.3.5 Boundaries for roller shutter boxes

Calculation of the thermal transmittance of a roller shutter box shall be done with the following boundary conditions:

— the top of the roller shutter box: adiabatic;

— at the bottom of the roller shutter box where it adjoins the window frame: adiabatic for a distance of 60 mm;

— surfaces adjacent to the internal environment: surface resistance of 0,13 $m^2 \cdot K/W$;

— surfaces adjacent to the external environment: surface resistance of 0,04 $m^2 \cdot K/W$.

The cavity within the roller shutter box shall be treated as (see Figure 2):

— if $e_1 + e_3 \leq 2$ mm: unventilated; the equivalent thermal conductivity of an unventilated air cavity is calculated according to 6.4.2.3;

NOTE Additional hardware like brushes, gaskets, etc. can be taken into account for the determination of e_1 and e_3.

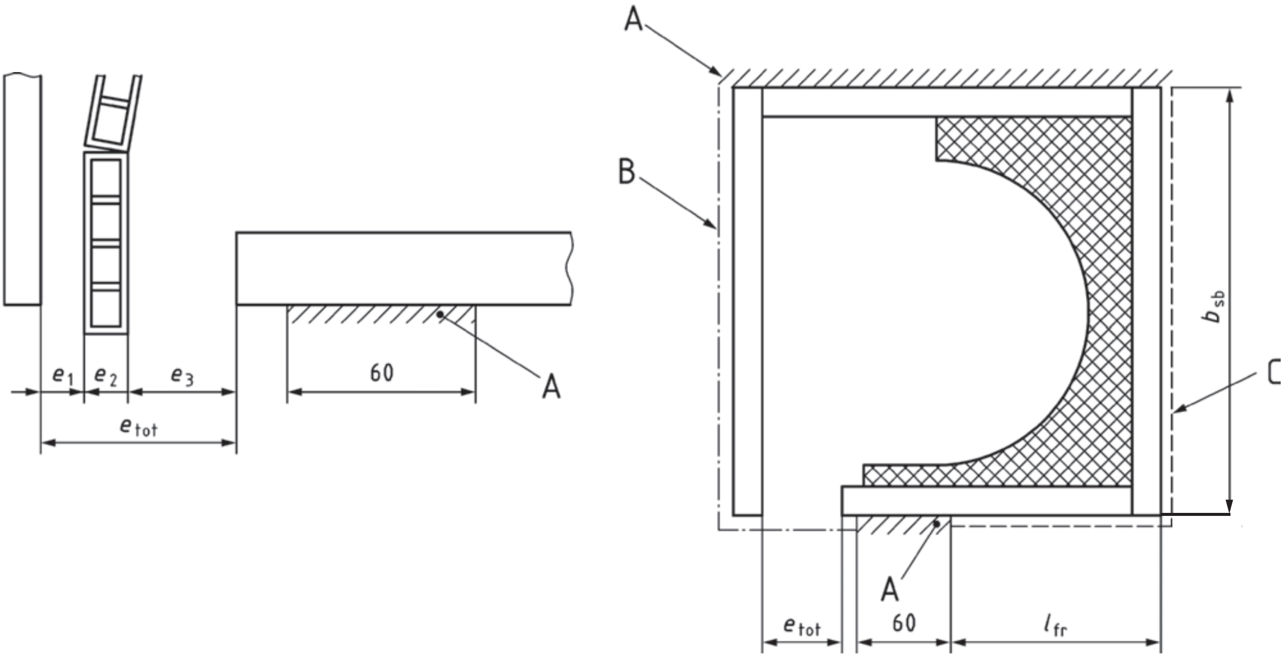
— if $e_{tot} \leq 35$ mm: slightly ventilated; taking the air temperature within the cavity equal to the external air temperature but with a surface resistance of 0,30 $m^2 \cdot K/W$;

— if $e_{tot} > 35$ mm: well-ventilated; taking the air temperature within the cavity equal to the external air temperature but with a surface resistance of 0,13 $m^2 \cdot K/W$.

The relevant height of the roller shutter box, b_{sb}, used for the calculation is the projected distance between the upper and lower adiabatic boundary (see Figure 2).

The assessment may be done with insulation on either or both of the boundaries B and C indicated in Figure 2. If that is the case the thickness and thermal conductivity of the insulation shall be stated in the calculation report.

Dimensions in millimetres



Key

Boundaries (see Annex E):

A adiabatic boundary

B external surface resistance

C internal surface resistance

b_{sb} height of the roller shutter box

e_1, e_3 widths of air gaps on either side of the shutter were it exits from the shutter box

e_2 thickness of the shutter

e_{tot} $e_1 + e_2 + e_3$

l_{fr} position of the frame

NOTE The window frame (boundary A) is 60 mm wide but located with respect to the roller shutter box according to the actual situation.

Figure 2 — Schematic example for the treatment of the boundaries for roller shutter boxes

6.4 Calculation procedures

6.4.1 Determination of thermal transmittance

The thermal transmittance of a frame section shall be determined with the glazing replaced by an insulating panel according to Annex F, with the external and internal surface resistances taken from Annex E. The linear thermal transmittance of the interaction of frame and glazing shall be determined from calculations with the glazing in place and with the glazing replaced by an insulated panel.

NOTE 1 The interaction of the frame and the building structure is considered separately for the building as a whole. It is not part of the thermal transmittance of the frame section.

NOTE 2 In the case of an overlap between the frame section and part of the wall, the linear thermal transmittance could be negative.

6.4.2 Treatment of cavities using the radiosity method

6.4.2.1 General

The heat transfer through an air cavity occurs simultaneously through convection and through radiation. The two phenomena are happening in parallel so that the calculation of each contribution can be done separately.

The calculation of the convective heat transfer is carried out using an equivalent thermal conductivity and following the rules of 6.4.2.3.2. Given that the formula for the equivalent thermal conductivity applies to rectangular cavities with the convective heat flow parallel to the depth of the cavity only, non-rectangular cavities or rectangular cavities with the convective heat flow not parallel to the depth of the cavity must be first transformed into equivalent rectangular cavities, correctly oriented with regards to the direction of the convective heat flow.

The calculation of the radiative heat transfer is carried out for the real geometry of the cavities (but after applying the subdivision rule for interconnected cavities, see 6.4.2.3.1) using a view factor-based radiosity method, as explained in 6.4.2.3.3.

Both convective and radiative heat transfer calculations depend on the temperature itself (nonlinear calculations). Therefore, an iterative calculation procedure of the heat flow shall be adopted.

Figure 3 shows the flowchart of the general methodology.

NOTE 1 In contrast to other standards and to 6.4.3, the equivalent thermal conductivity here includes only the effect of the convective heat transfer (radiative heat transfer is taken into account separately).

NOTE 2 The terms “convective heat transfer” and “convective heat flow” are used to represent heat transfer by both conduction and convection.

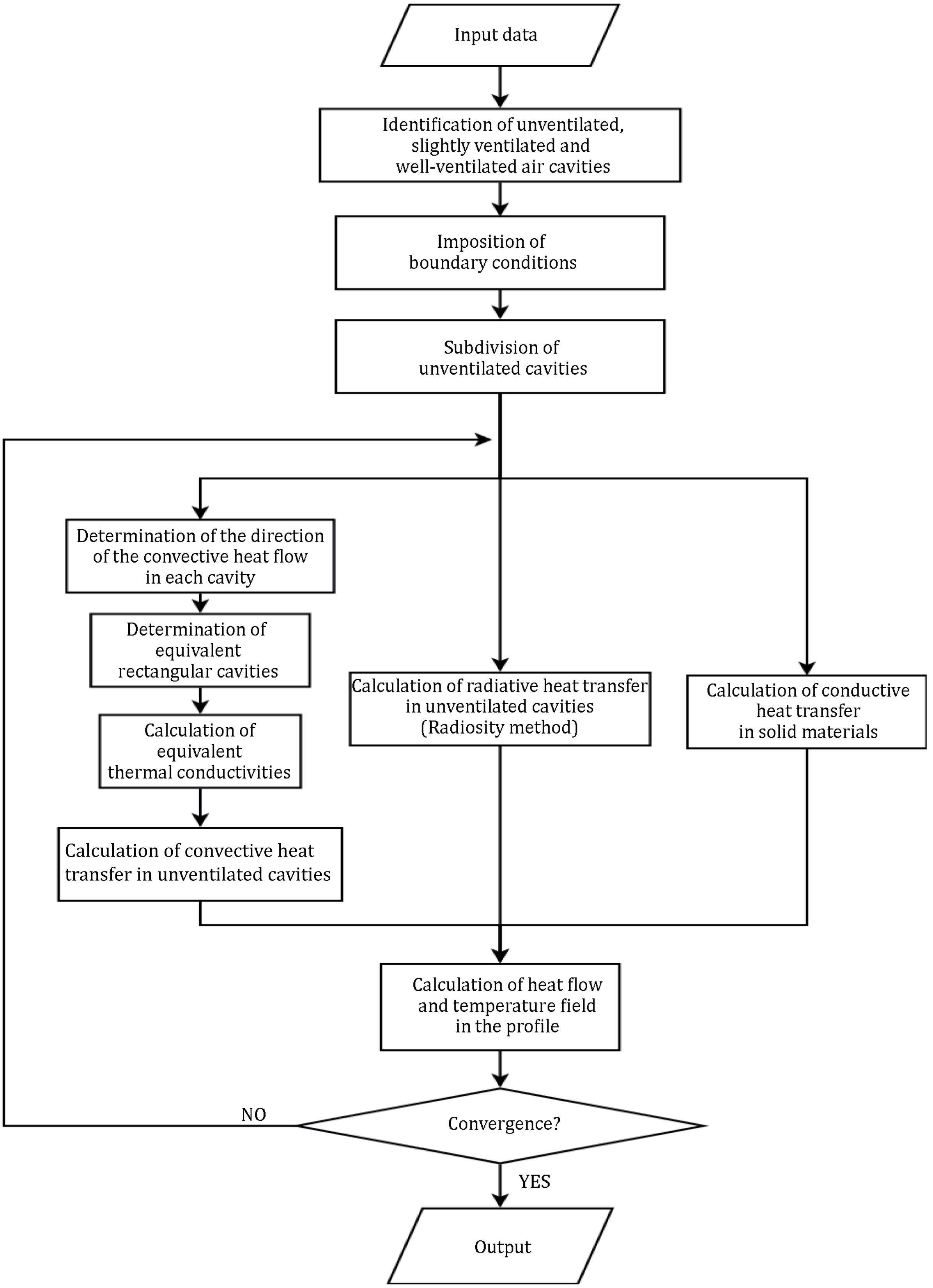


Figure 3 — Flowchart of the calculation method

6.4.2.2 Cavities in glazing

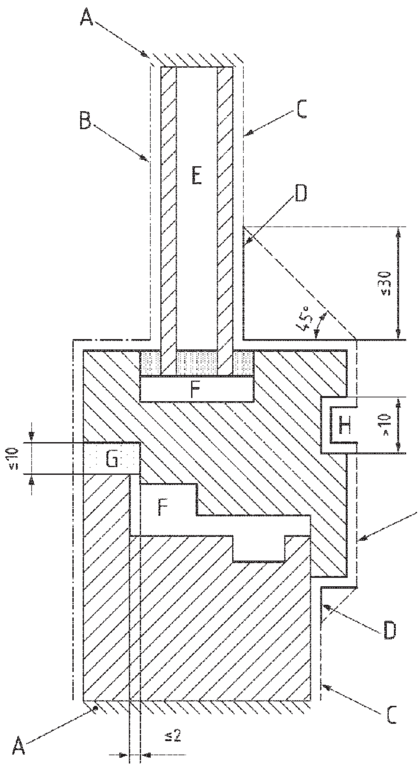
The equivalent thermal conductivity of an unventilated space between glass panes in glazing shall be determined according to ISO 10292 (or see Subject 1 in Table C.1). The resulting equivalent conductivity shall be used in the whole cavity, up to the edge.

6.4.2.3 Unventilated air cavities in frames and roller shutter boxes

6.4.2.3.1 Definition

Air cavities are unventilated if they are completely closed or connected either to the exterior or to the interior by a slit with a width not exceeding 2 mm (see Figures 4 and 5); this applies irrespective of the orientation of the cavity with respect to heat flow direction. Otherwise the cavity shall be treated as ventilated or slightly ventilated (see 6.4.2.4).

Dimensions in millimetres



Key

Boundaries (see Annex E):

A adiabatic boundary

B external surface resistance

C internal surface resistance

D increased surface resistance

E glazing (see 6.4.2.2)

F unventilated cavity (see 6.4.2.3)

G slightly ventilated cavity or groove (see 6.4.2.4.1)

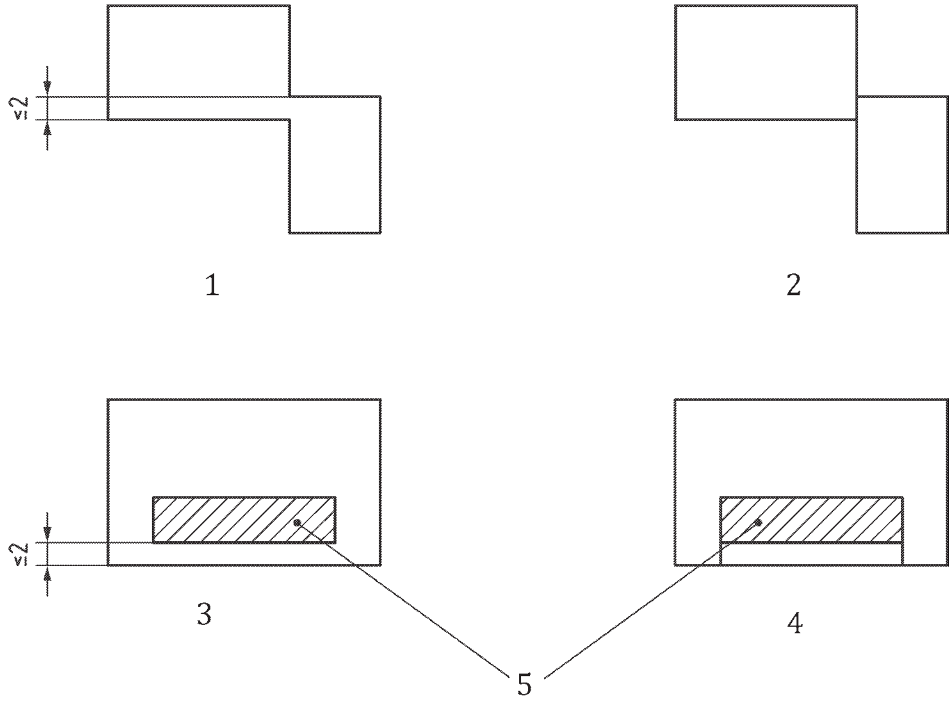
H well-ventilated cavity or groove (see 6.4.2.4.2)

Figure 4 — Schematic example for the treatment of boundaries and cavities and grooves of a frame section

NOTE Figure 4 illustrates a window. The same principles are applicable to roof windows, but the adiabatic part of the boundary is different: An example of a roof window is shown in Figure H.6.

Cavities with one dimension not exceeding 2,0 mm or cavities with an interconnection not exceeding 2,0 mm shall be considered as separate, see Figure 5.

Dimensions in millimetres



Key

1 cavities connected by a section less than or equal to 2 mm

2 cavities in 1 treated as separated cavities

3 small cavity with a width less than or equal to 2,0 mm

4 cavity in 3 treated as separated cavities

5 solid material

Figure 5 — Division of cavity

6.4.2.3.2 Convective heat transfer in unventilated air cavities

In order to calculate the convective heat transfer in a cavity, an equivalent thermal conductivity is used. Its value is given by Formula (1):

$$\lambda_{eq} = \lambda_{air} \cdot Nu \tag{1}$$

where

λ_{air} is the thermal conductivity of air = 0,025 W/(m·K);

Nu is the Nusselt number.

The Nusselt number is calculated as follows:

if b < 5 mm: Nu = 1

otherwise

$$Nu = \max\left[1, \frac{dC\Delta T^{1/3}}{\lambda_{air}}\right] \quad (2)$$

where

- b is the width of the equivalent rectangular cavity perpendicular to the direction of heat flow, in m (see also Figure 6);
- d is the depth of the equivalent rectangular cavity in the direction of heat flow, in m (see also Figure 6);
- C is a constant equal to 0,73 W/(m^2·K$^{4/3}$);
- ΔT is the maximum surface temperature difference in the real cavity, in K.

As ΔT is initially unknown, the calculation of the convective heat transfer is iterative. A temperature difference of 10 K can be considered for the first iteration.

In order to calculate the convective heat transfer in non-rectangular cavities or in rectangular cavities with the convective heat flow not parallel to the depth of the cavity, these cavities are first transformed into equivalent rectangular cavities.

Air cavities are transformed into equivalent rectangular air cavities with the same area ($A = A'$) and aspect ratio ($d/b = d'/b'$), see Figure 6.

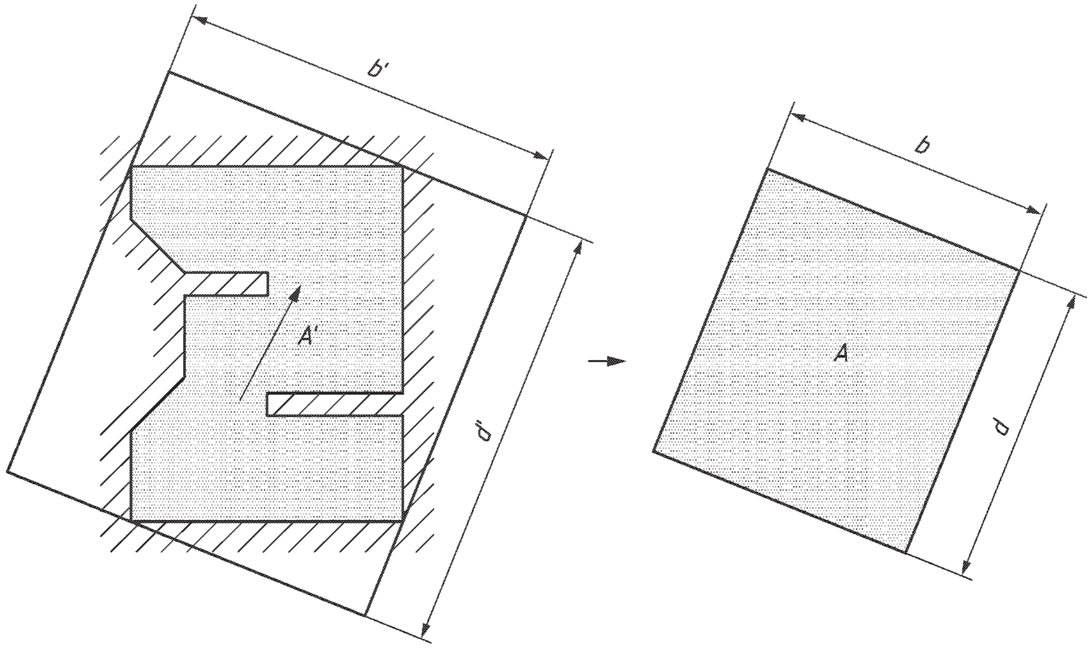
The transformation is given by Formulae (3) and (4):

$$b = \sqrt{A'\frac{b'}{d'}} \quad (3)$$

$$d = \sqrt{A'\frac{d'}{b'}} \quad (4)$$

The calculation of the dimensions of the equivalent rectangular cavity requires the determination of the convective heat flow direction.

The convective heat flow direction in the cavity is a direction in the cross-sectional plane of the frame section corresponding to the main direction of the convective heat flow in the cavity.



Key

A	area of the equivalent rectangular air cavity
d, b	depth and width of the equivalent air cavity
A′	area of the true cavity
d′, b′	depth and width of the circumscribing rectangle with *d′* parallel to the convective heat flow direction

Figure 6 — Transformation of air cavities

From a known temperature distribution in the cavity as shown in Figure 7 the convective heat flow direction equals the direction of the vector $\overline{q}_{\mathrm{m}}$ calculated as Formula (5):

$$\overline{q}_{\mathrm{m}} = \frac{\int_A \overline{q}\, dA}{A} = \frac{\int_A -\lambda_{\mathrm{eq}} \mathrm{grad} T\, dA}{A} \tag{5}$$

where

$\overline{q}_{\mathrm{m}}$	is the mean heat flow density, in $\mathrm{W/m^2}$;
$\overline{q}$	is the local heat flow density, in $\mathrm{W/m^2}$;
A	is the cross-sectional area of the cavity, in $\mathrm{m^2}$;
λ_{eq}	is the equivalent thermal conductivity of the cavity, in W/(m·K);
grad$T$	is the temperature gradient of the gas within the cavity, in K/m.

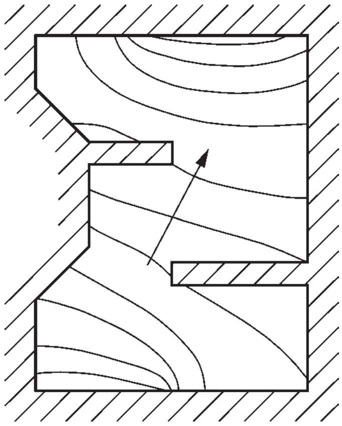


Figure 7 — Cavity conductive heat flow direction

As the temperature field, and therefore, the direction of the convective heat flow are initially unknown, the calculation of the convective heat transfer is iterative.

6.4.2.3.3 Radiative heat exchange

The radiative heat exchange between the elementary surfaces around the air cavity (resulting from the grid used by the numerical method) shall be calculated using the radiosity method. The radiosity method assumes isothermal elementary surfaces to be characterized by a uniform radiosity and irradiance. The surfaces are assumed to have opaque, diffuse and grey surface behaviour. The air within the cavity is taken to be non-participating (i.e. the gas does not absorb radiation).

NOTE 1 Definitions of the terms radiosity, irradiance, opaque, diffuse and grey are given in ISO 9288.

The radiative heat exchange according to the radiosity method can be represented by a thermal resistance network as shown, for example, in Figure 8.

NOTE 2 Only four elementary surfaces occur in the network shown. In real cavities, multiple elementary surfaces will occur.

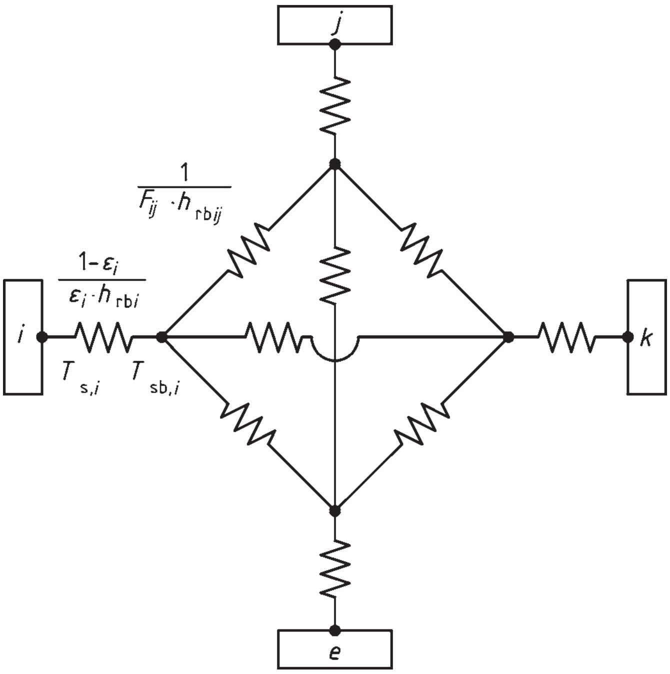


Figure 8 — Example of radiation thermal resistance network

The network is specified as follows:

— in the surface node i, the temperature T_{si} is applied;

— the node adjacent to the surface node i (so-called black surface node i) has temperature T_{sbi};

— the radiative heat flow between two black surface nodes i and j is defined in Formulae (6), (7) and (8):

$$Q_{ij} = \frac{A_i \left(T_{\mathrm{sb}i} - T_{\mathrm{sb}j} \right)}{R_{ij}} \tag{6}$$

$$R_{ij} = \frac{1}{F_{ij}\, h_{\mathrm{rb},ij}} \tag{7}$$

$$h_{\mathrm{rb},ij} = \sigma \left(T_{\mathrm{sb}i}^2 + T_{\mathrm{sb}j}^2 \right) \left(T_{\mathrm{sb}i} + T_{\mathrm{sb}j} \right) \tag{8}$$

where

A_i is area of elementary surface i, in m²;

F_{ij} is the view factor from surface i to surface j;

$h_{\mathrm{rb},ij}$ is the black radiation heat transfer coefficient between surface node i and surface node j, in W/(m²·K);

σ is the Stefan-Boltzmann constant equal to 5,67 × 10^{-8} W/(m²·K⁴);

$T_{\mathrm{sb}i}$ is absolute temperature of black surface node i, in K;

$T_{\mathrm{sb}j}$ is absolute temperature of black surface node j, in K;

— The radiative heat flow between a black surface node i and a surface node i is defined in Formulae (9), (10) and (11):

$$Q_i = \frac{A_i \left(T_{\mathrm{sb}i} - T_{si} \right)}{R_i} \tag{9}$$

$$R_i = \frac{1 - \varepsilon_i}{\varepsilon_i\, h_{\mathrm{rb}i}} \tag{10}$$

$$h_{\mathrm{rb}i} = \sigma \left(T_{\mathrm{sb}i}^2 + T_{si}^2 \right) \left(T_{\mathrm{sb}i} + T_{si} \right) \tag{11}$$

where

A_i is the area of the elementary surface i, in m²;

ε_i is the total hemispherical emissivity of surface i;

$h_{\mathrm{rb}i}$ is the black radiation heat transfer coefficient between surface node i and black surface node i,
in W/(m²·K);

σ is the Stefan-Boltzmann constant equal to 5,67 × 10^{-8} W/(m^2·K^4);

T_{si} is the absolute temperature of surface node i, in K;

T_{sbi} is the absolute temperature of black surface node i, in K.

The view factor between two infinitesimal surfaces dA_1 and dA_2 is defined in Formula (12):

$$F_{dA1\rightarrow dA2} = \frac{\cos\varphi_1 \cos\varphi_2 \, dA_2}{\pi r^2} \tag{12}$$

where

φ_1 is the angle between the line connecting the two infinitesimal surfaces and the normal of the surface dA_1;

φ_2 is the angle between the line connecting the two infinitesimal surfaces and the normal of the surface dA_2;

r is the distance between the two infinitesimal surfaces.

φ_1, φ_2 and r are shown in Figure 9.

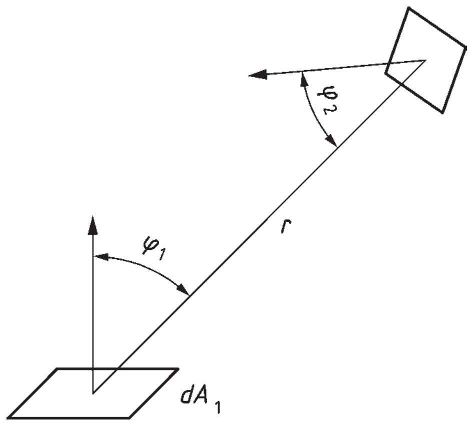


Figure 9 — Definition of the view factor between two infinitesimal surfaces

The view factor between the elementary surfaces A_i and A_j is obtained by integration; see Formula (13):

$$F_{ij} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{\cos\varphi_i \cos\varphi_j}{\pi r^2} dA_i \, dA_j \tag{13}$$

The calculation of the view factors shall take into account the effects of shading or blocking by intervening surfaces.

As the network resistances depend on the node temperatures, the radiation exchange calculation is iterative.

Small openings can occur in the cavity surface (due to slits or interconnections with a width not exceeding 2 mm, see 6.4.2.3.1). These small openings can be treated as a surface with zero emissivity.

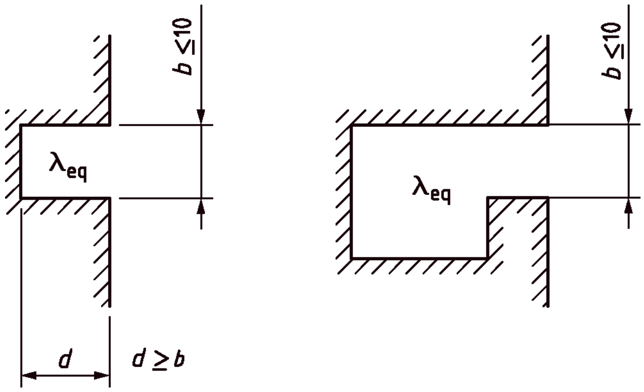
Where a cavity has an adiabatic boundary, this boundary can be treated as a surface with zero emissivity.

6.4.2.4 Ventilated air cavities and grooves

6.4.2.4.1 Slightly ventilated cavities and grooves with small cross section

Grooves with small cross sections (see Figure 10) at the external or internal surfaces of profiles and cavities connected to the external or internal air by a slit greater than 2 mm but not exceeding 10 mm shall be considered as slightly ventilated air cavities. In this case, it is assumed that the whole surface is exposed to the environment and a surface resistance R_s = 0,30 m²·K/W shall be used at the developed surface, see Figure 10. Additional hardware like brushes, gaskets, etc. can be taken into account for the determination of *b*.

Dimensions in millimetres



Key

λ_{eq} equivalent thermal conductivity

Figure 10 — Examples for slightly ventilated cavities and grooves with small cross section

6.4.2.4.2 Well-ventilated cavities and grooves with large cross section

In cases not covered by 6.4.2.3 and 6.4.2.4.1, in particular when the width *b* of a groove or of a slit connecting a cavity to the environment exceeds 10 mm, it is assumed that the whole surface is exposed to the environment. Therefore, the surface resistance R_{si} or R_{se} according to 6.3.4 shall be used at the developed surface, see Figure 11. Additional hardware like brushes, gaskets, etc. can be taken into account for the determination of *b*.

In the case of a large cavity connected by a single slit and a developed surface exceeding the width of the slit by a factor of 10, the surface resistance with reduced radiation shall be used (see Annex E).

Dimensions in millimetres

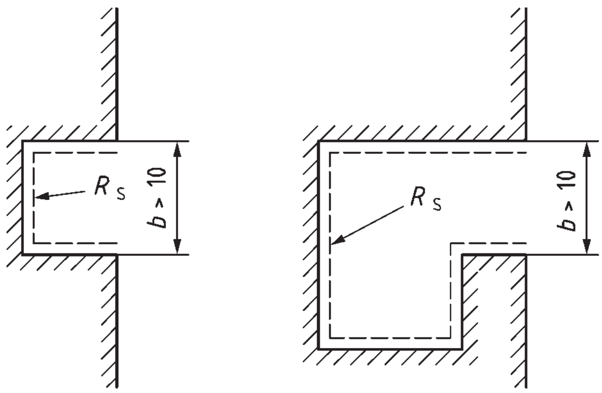


Figure 11 — Examples for well-ventilated cavities and grooves

6.4.3 Treatment of cavities using the single equivalent thermal conductivity method

6.4.3.1 General

The heat flow rate in cavities shall be represented by a single equivalent thermal conductivity, λ_{eq}. This equivalent thermal conductivity includes the heat flow by conduction, by convection and by radiation, and depends on the geometry of the cavity and on the adjacent materials.

6.4.3.2 Cavities in glazing

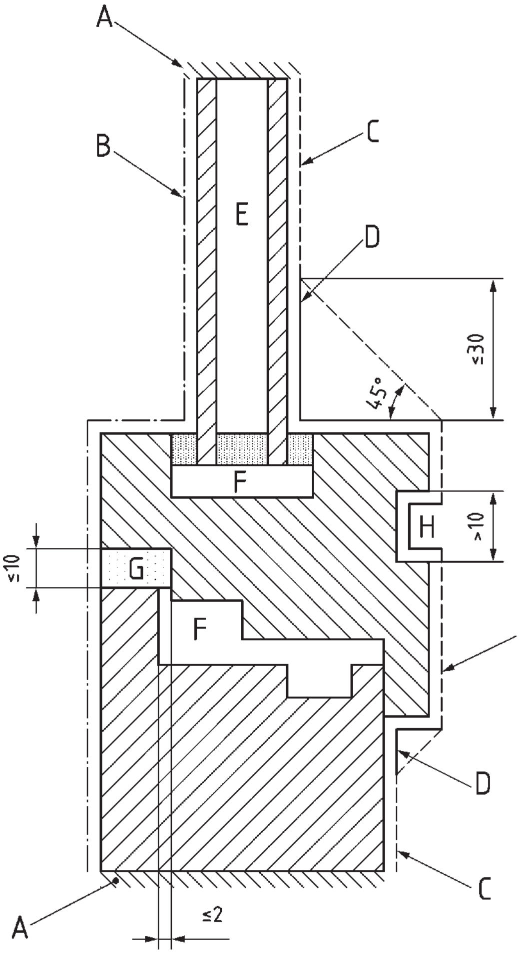
The equivalent thermal conductivity of an unventilated space between glass panes in glazing shall be determined according to ISO 10292 (or see Subject 1 in Table C.1). The resulting equivalent conductivity shall be used in the whole cavity, up to the edge.

6.4.3.3 Unventilated air cavities in frames and roller shutter boxes

6.4.3.3.1 Definition

Air cavities are unventilated if they are completely closed or connected either to the exterior or to the interior by a slit with a width not exceeding 2 mm (see Figures 12 and 13); this applies irrespective of the orientation of the cavity with respect to heat flow direction. Otherwise, the cavity shall be treated as ventilated or slightly ventilated (see 6.4.3.6).

Dimensions in millimetres



Key

Boundaries (see Annex E):

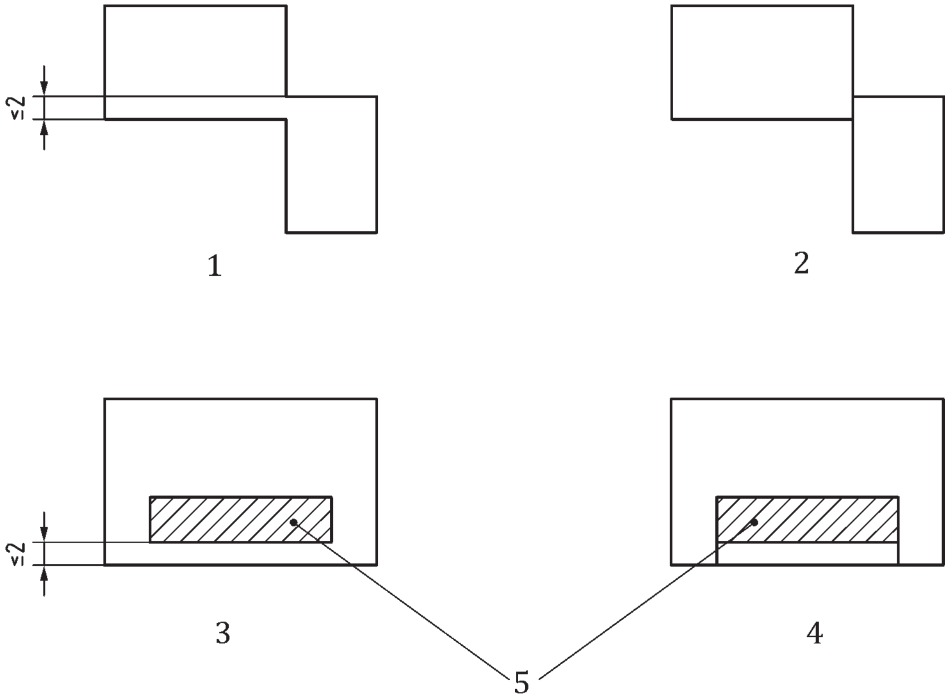
A	adiabatic boundary	E	glazing (see 6.4.3.2)
B	external surface resistance	F	unventilated cavity (see 6.4.3.3)
C	internal surface resistance	G	slightly ventilated cavity or groove (see 6.4.3.4.1)
D	increased surface resistance	H	well-ventilated cavity or groove (see 6.4.3.4.2)

Figure 12 — Schematic example for the treatment of boundaries and cavities and grooves of a frame section

NOTE Figure 12 illustrates a window. The same principles are applicable to roof windows, but the adiabatic part of the boundary is different. An example of a roof window is shown in Figure H.6.

Cavities with one dimension not exceeding 2,0 mm or cavities with an interconnection not exceeding 2,0 mm shall be considered as separate; see Figure 13.

Dimensions in millimetres



Key

1 cavities connected by a section less than or equal to 2 mm

2 cavities in 1 treated as separated cavities

3 small cavity with a width less than or equal to 2,0 mm

4 cavity in 3 treated as separated cavities

5 solid material

Figure 13 — Division of cavity

6.4.3.4 Unventilated rectangular air cavities

6.4.3.4.1 Equivalent thermal conductivity

The equivalent thermal conductivity, λ_{eq}, of the cavity in direction 1 (see Figure 14) is given by Formula (14):

$$\lambda_{eq} = \frac{d}{R_s} \tag{14}$$

where

d is the dimension of the cavity in the direction of heat flow (see Figure 14);

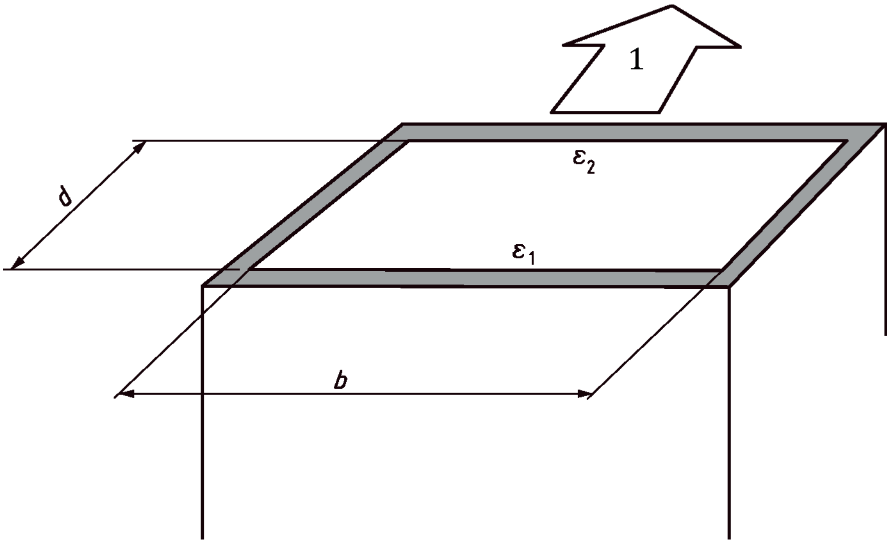
R_s is the thermal resistance of the cavity, given by Formula (15):

$$R_s = \frac{1}{h_c + h_r} \tag{15}$$

where

h_c is the convective heat transfer coefficient;

h_r is the radiative heat transfer coefficient.



Key

1 heat flow direction

b dimension perpendicular to the direction of heat flow

d dimension of cavity in the direction of heat flow

ε_1, ε_2 emissivities of the surfaces

Figure 14 — Rectangular cavity

6.4.3.4.2 Convective heat transfer coefficient

The convective heat transfer coefficient, h_c, is

if b < 5 mm,

$$h_c = \frac{C_1}{d} \tag{16}$$

where

C_1 = 0,025 W/(m·K);

otherwise

$$h_c = \max\left\{\frac{C_1}{d}; C_2 \Delta T^{1/3}\right\} \tag{17}$$

where

C_1 = 0,025 W/(m·K);

C_2 = 0,73 W/(m^2·K$^{4/3}$);

ΔT is the maximum surface temperature difference in the cavity.

If no other information is available, use ΔT = 10 K for which

$$h_c = \max\left\{\frac{C_1}{d}; C_3\right\} \quad (18)$$

where

C_1 = 0,025 W/(m·K);

C_3 = 1,57 W/(m^2·K).

6.4.3.4.3 Radiative heat transfer coefficient

$$h_r = 4\sigma T_m^3 \; E \; F \quad (19)$$

where

σ is the Stefan-Boltzmann constant equal to 5,67 × 10^{-8} W/(m^2·K^4);

E is the intersurface emittance equal to $\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)^{-1}$;

F is the view factor for a rectangular section equal to $\frac{1}{2}\left(1 + \sqrt{1 + \left(d/b\right)^2} - d/b\right)$.

ε_1 and ε_2 are the emissivities of the surfaces indicated in Figure 14.

The values of the emissivities should be given to two decimal places. If no other information is available, use ε_1 = 0,90 and ε_2 = 0,90.

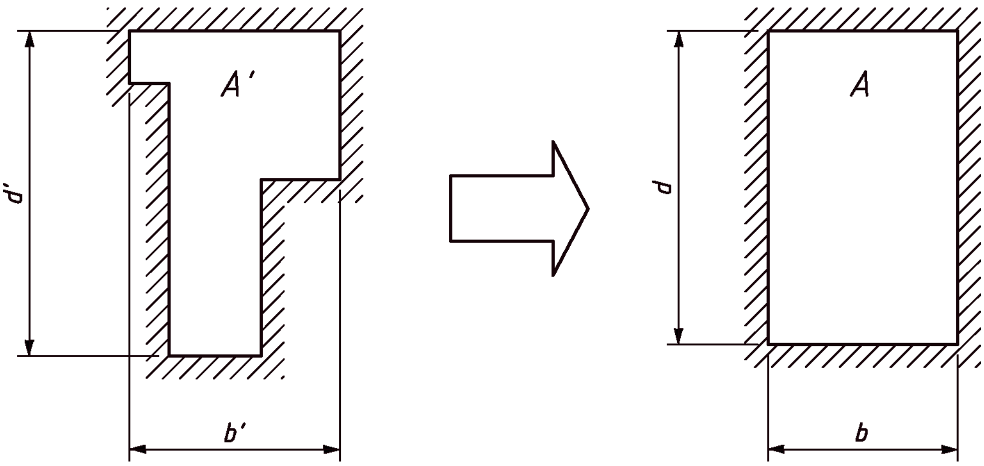
If no other information is available, use T_m = 283 K for which

$$h_r = C_4 \left(1 + \sqrt{1 + \left(d/b\right)^2} - d/b\right) \quad (20)$$

where C_4 = 2,11 W/(m^2·K).

6.4.3.5 Unventilated non-rectangular air cavities

Non-rectangular air cavities (T-shape, L-shape, etc.) are transformed into rectangular air cavities with the same area ($A = A'$) and aspect ratio ($d/b = d'/b'$) (see Figure 15) and then 6.4.3 is applied.



Key

A	area of the equivalent rectangular air cavity
d, b	depth and width of the equivalent air cavity
A'	area of the true cavity
d' b'	depth and width of the smallest circumscribing rectangle

Figure 15 — Transformation of non-rectangular air cavities

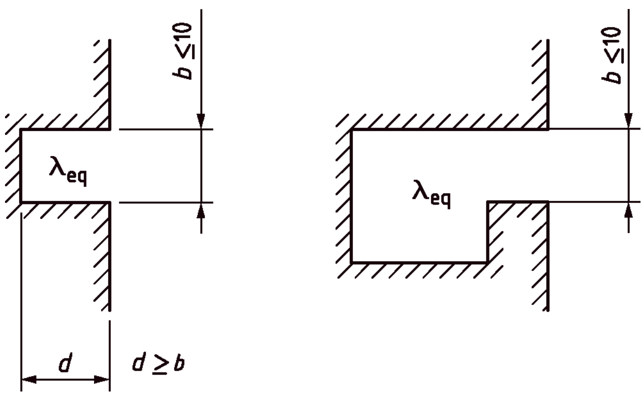
The transformation is given by Formulae (3) and (4).

6.4.3.6 Ventilated air cavities and grooves

6.4.3.6.1 Slightly ventilated cavities and grooves with small cross section

Grooves with small cross sections (see Figure 16) at the external or internal surfaces of profiles and cavities connected to the external or internal air by a slit greater than 2 mm but not exceeding 10 mm shall be considered as slightly ventilated air cavities. The equivalent conductivity is twice that of an unventilated air cavity of the same size according to 6.4.3.3. Additional hardware like brushes, gaskets, etc. can be taken into account for the determination of *b*.

Dimensions in millimetres



Key

λ_{eq} equivalent thermal conductivity

Figure 16 — Examples of slightly ventilated cavities and grooves with small cross-section

6.4.3.6.2 Well-ventilated cavities and grooves with large cross section

In cases not covered by 6.4.3.3 and6.4.3.6.1, in particular when the width *b* of a groove or of a slit connecting a cavity to the environment exceeds 10 mm, it is assumed that the whole surface is exposed to the environment. Therefore, the surface resistance R_{si} or R_{se} according to 6.3.4 shall be used at the developed surface; see Figure 17. Additional hardware like brushes, gaskets, etc. can be taken into account for the determination of *b*.

In the case of a large cavity connected by a single slit and a developed surface exceeding the width of the slit by a factor of 10, the surface resistance with reduced radiation shall be used (see Annex E).

Dimensions in millimetres

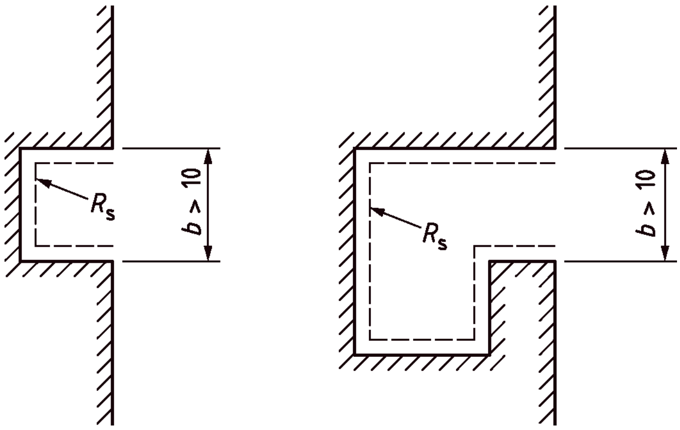


Figure 17 — Examples for well-ventilated cavities and grooves

7 Report

7.1 Contents of report

The calculation report shall include the following:

— reference to this document, i.e. ISO 10077-2;

— identification of the organization making the calculation;

— identification of the calculation programme;

— date of calculation;

— applied calculation method for cavities: radiosity method (6.4.2) or single equivalent thermal conductivity method (6.4.3); date of calculation;

— items listed in 7.2 and 7.3.

7.2 Geometrical data

A technical drawing of the sections (preferably using 1:1 scale) shall be included in the report. The drawing shall give the dimensions and a description of the materials used. The minimum information to be given are:

— for metallic frames, the thickness, position, type and number of thermal breaks;

— for plastic frames, the presence and position of metal stiffening (reinforcements);

— the thickness of wooden or plastic frames, preferably indicated on a scale drawing;

— the internal and external projected frame areas, preferably indicated on a scale drawing;

— the depth and the thickness of the glazing or panel in the frame;

— for a roller shutter box, the dimensions of the roller shutter box, the position of the window frame and the ventilation of the cavity (see 6.3.5).

7.3 Thermal data

7.3.1 Thermal conductivity

All materials of the frame section shall be listed together with the thermal conductivity values used for the calculation. The data given in Annex D should be used. If other sources are used, this shall be clearly stated and reference made to the sources.

7.3.2 Emissivity

For cavities, the emissivity of the surrounding surfaces shall be stated with reference to Table D.3 where appropriate, and supporting evidence, including references, shall be provided if values less than 0,9 are used.

7.3.3 Boundary conditions

The internal and external surface resistances and the adiabatic boundaries, together with the internal and external air temperature, shall be indicated on the drawing. The internal and external surface resistances, as well as the internal and external air temperatures may alternatively also be indicated in a table.

In the case of a roller shutter box, the location of any insulation applied to the surfaces of the roller shutter box shall be stated, together with its thickness and thermal conductivity.

7.4 Presentation of results

The total heat flow rate or the density of heat flow rate, the thermal transmittance of the frame section or the roller shutter box and the linear thermal transmittance according to Annex F shall be given to two significant figures (i.e. to one decimal place if ≥1,0, to two decimal places if <1,0 and to three decimal places if <0,1).

Annex A
(normative)

Input and method selection data sheet — Template

A.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other documents.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section “Introduction” of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

A.2 References

The references, identified by the EPB module code number, are given in Table A.1 (template).

Table A.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...
	...	...

[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards

A.3 Calculation of thermal transmittance

NOTE Currently in this document, there are no choices between methods and the required input data foreseen that are to be kept open for completion as explained in A.1. To satisfy the need for congruence with all other EPB standards and to make explicitly clear that in this document there are no choices kept open, this annex and Annex B are kept.

Annex B
(informative)

Input and method selection data sheet — Default choices

B.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other documents.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section "Introduction" of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

B.2 References

The references, identified by the EPB module code number, are given in Table B.1.

Table B.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...
	...	...

[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards.

B.3 Calculation of thermal transmittance

NOTE Currently in this document, there are no choices between methods and the required input data foreseen that are to be kept open for completion as explained in B.1. To satisfy the need for congruence with all other EPB standards and to make explicitly clear that in this document there are no choices kept open, this annex and Annex B are kept.

Annex C
(normative)

Regional references in line with ISO Global Relevance Policy

This document contains specific parallel routes in referencing other standards, in order to take into account existing national and/or regional regulations and/or legal environments, while maintaining global relevance.

The standards that shall be used as called for in the successive clauses are given in Table C.1.

Table C.1 — Regional references in line with ISO Global Relevance Policy

Subject		Global	CEN area[a]
1	equivalent thermal conductivity — glazing	ISO 10292	EN 673

[a] CEN area = Countries whose national standards body is a member of CEN. Attention is drawn to the need for observance of EU Directives transposed into national legal requirements.

Annex D
(normative)

Thermal conductivity and other characteristics of selected materials

Table D.1 includes the thermal conductivities of the materials used for the given groups. With a few exceptions, the values were taken from ISO 10456, which also includes other materials.

Table D.1 — Thermal conductivities of materials

Group	Material[a]	Density kg/m^3	Thermal conductivity W/(m·K)
Frame	Copper	8 900	380
	Aluminium (Si alloys)	2 800	160
	Brass	8 400	120
	Steel	7 800	50
	Stainless steel[b], austenitic or austenitic-ferritic	7 900	17
	Stainless steel[b], ferritic or martensitic	7 900	30
	PVC (polyvinylchloride), rigid	1 390	0,17
	Hardwood[c]	700	0,18
	Softwood[d]	500	0,13
	Softwood[d]	450	0,12
	Fibreglass (UP-resin)*	1 900	0,40
Glass	Soda lime glass	2 500	1,00
	PMMA (polymethylmethacrylate)	1 180	0,18
	Polycarbonates	1 200	0,20
Thermal break	ABS (acrylonitrile butadiene styrene)	1 050	0,20
	Polyamide (nylon)	1 150	0,25
	Polyamide 6,6 with 25 % glass fibre	1 450	0,30
	Polyethylene HD, high density	980	0,50
	Polyethylene LD, low density	920	0,33
	Polypropylene, solid	910	0,22
	Polypropylene with 25 % glass fibre	1 200	0,25
	PU (polyurethane), rigid	1 200	0,25
	PVC-U (polyvinylchloride), rigid	1 390	0,17

[a] Most materials are taken from ISO 10456, except those marked with an asterisk (*).

[b] EN 10088–1 contains extensive lists of properties of stainless steels which may be used when the precise composition of the stainless steel is known.

[c] Hardwood refers to wood of trees of the botanical group dicotyledonae; see also Annex J.

[d] Softwood refers to wood of trees of the botanical group gymnosperms; see also Annex J.

Table D.1 *(continued)*

Group	Material[a]	Density kg/m^3	Thermal conductivity W/(m·K)
Weather stripping	PCP (polychloroprene), e.g. polychloroprene	1 240	0,23
	EPDM (ethylene propylene diene monomer)	1 150	0,25
	Silicone, pure	1 200	0,35
	Silicone, filled	1 450	0,50
	PVC, flexible (PVC-P) 40 % softener	1 200	0,14
	Pile weather stripping (polyester mohair)*		0,14
	Elastomeric foam, flexible	60 to 80	0,05
Sealant and glass edge material	PU (polyurethane)	1 500	0,40
	Butyl rubber, solid/hot melt	1 200	0,24
	Polysulfide	1 700	0,40
	Silicone, pure	1 200	0,35
	Silicone, filled*	1 450	0,40
	Polyisobutylene	930	0,20
	Polyester resin	1 400	0,19
	Silica gel (desiccant)	720	0,13
	Molecular sieve(desiccant)*	650 to 750	0,10
	Silicone foam, low density	750	0,12
	Silicone foam, medium density*	820	0,17

[a] Most materials are taken from ISO 10456, except those marked with an asterisk (*).

[b] EN 10088–1 contains extensive lists of properties of stainless steels which may be used when the precise composition of the stainless steel is known.

[c] Hardwood refers to wood of trees of the botanical group dicotyledonae; see also Annex J.

[d] Softwood refers to wood of trees of the botanical group gymnosperms; see also Annex J.

For the application of this document, the thermal conductivity of timber can be taken from Table D.2, depending on the timber species.

Table D.2 — Thermal conductivity of timber species

Code for timber species[a]	Thermal conductivity, λ W/(m·K)
ABAL, PCAB, PCST, PNCN, THPL	0,11
KHXX, LADC, LAER, LAGM, LAOC, LAXX, PCGL, PHWS, PNSY, PSMN, SHLR, SWMC, TMIV, TSHT	0,13
ENCY, ENUT, EUXX, HEXM, HEXN, MIXX, OCRB, SHDR, TEGR, TGHC	0,16
AFXX, CLXX, EUGL, EUGR, EUSL, EUUG, EUUP, INXX, PHMG, PMPN, QCXA, QCXE, ROPS	0,18

[a] Annex J contains the list of wood species designated by these codes.

For the application of this document, the emissivity of metallic surfaces can be taken from Table D.3, depending on the treatment of the surface.

Table D.3 — Typical emissivities of metallic surfaces

Description	Normal emissivity
untreated aluminium surfaces	0,1
slightly oxidized aluminium surfaces (up to 5 μm)	0,3
metallic surfaces (general, including galvanized)	0,3
anodized, painted or powder coated surfaces	0,9
NOTE 1 An untreated surface is one that has had no artificial treatment (such as anodizing, galvanizing, painting). NOTE 2 Low emissivity can only be considered if soiling can be excluded.	

Annex E
(normative)

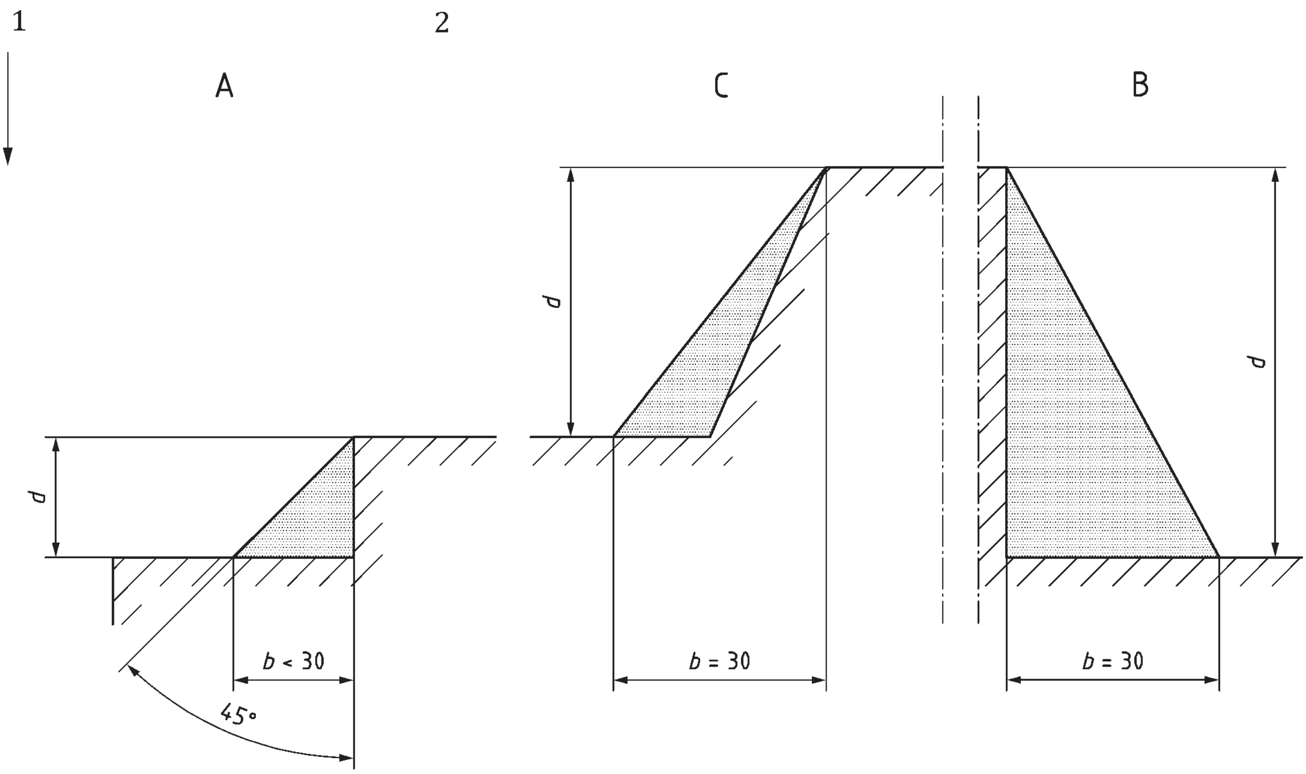
Surface resistances

Table E.1 — Surface resistances for profiles (horizontal heat flow)

Position	External, R_{se} m²·K/W	Internal, R_{si} m²·K/W
Normal (plane surface)	0,04	0,13
Reduced radiation/convection (in edges or junctions between two surfaces, see Figure E.1)	0,04	0,20
NOTE These values correspond to the surface resistance values given in ISO 6946, which also gives further information about the influence of convection and radiation on surface resistances.		

Where simulation software requires inclined surfaces to be represented by orthogonal meshing, the surface resistance may be corrected by multiplying by the ratio of the actual surface length to the length as represented in the simulation model.

Dimensions in millimetres



Key

1 direction of heat flow

2 internal surface

Figure E.1 — Schematic representation of surfaces with an increased surface resistance due to a reduced radiation/convection heat transfer

In Figure E.1, the shading indicates the distances over which increased surface resistances apply. These are the distances *b* and *d*, where *b* is equal to the depth *d*, but not greater than 30 mm.

Example 1 $b = d$ when $d \leq 30$ mm.

Example 2 $b = 30$ mm when $d > 30$ mm.

Example 3 For application to a sloped surface, $b = 30$ mm when $d > 30$ mm.

Table E.2 — Surface resistances for calculation of roller shutter boxes

Heat flow direction	External, R_{se} m^2·K/W	Internal, R_{si} m^2·K/W
Horizontal	0,04	0,13
Vertical	0,04	0,13
NOTE The value for the internal surface resistance for vertical heat flow takes into account the effect of heat flow in upward direction and also the effect of reduced radiation/convection.		

Annex F
(normative)

Determination of the thermal transmittance

F.1 Thermal transmittance of the frame section

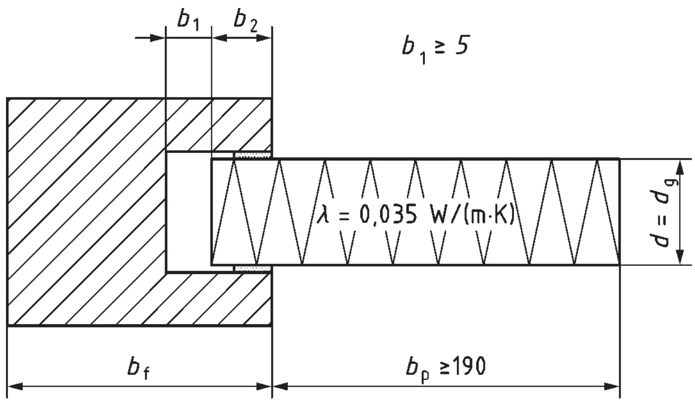
The thermal transmittance of the frame section, U_f, is defined as follows.

— With reference to Figure F.1, in the calculation model, the glazing or opaque panel is replaced by an insulation panel with thermal conductivity λ = 0,035 W/(m·K) inserted into the frame, with clearance b_1 not less than 5 mm. The overlap b_2 is equal to that of the glazing which the insulation panel replaces. The length of the panel shall be at least 190 mm measured from the most protruding part of the frame ignoring any protruding gasket(s). For protruding gaskets this means that the visible panel length could be less than 190 mm. The opposite end of the panel is considered as an adiabatic boundary. The frame model shall contain all materials used in manufacturing the window except the glazing or opaque panel, which is replaced by the insulation panel. The thickness d of the insulation panel shall be:

  — where the frame is designed for a specific thickness, that of the glazing or opaque panel being replaced;

  — where the frame can be used with several glazing thicknesses, 24 mm for double glazing or 36 mm for triple glazing.

Dimensions in millimetres



Key

b_f width of the frame

b_p width of the panel

d_g thickness of the glazing

Figure F.1 — Schematic of profile section with insulation panel installed

NOTE Figures H.1 to H.8 illustrate some typical window profiles, indicating the boundary conditions for the numerical calculations.

In the case of a roof window, the adiabatic parts of the boundary are those where the frame of the roof window is in contact with the roof, when the roof window is installed according to the manufacturer's instructions. If the method of installation of the roof window cannot be determined from the manufacturer's installation instructions, it shall be modelled as depicted in ISO 12567-2:2005, Figure 2.

The two-dimensional thermal conductance, L_f^{2D}, of the section shown in Figure F.1 consisting of frame and insulation panel is calculated. The value of the thermal transmittance of the frame, U_f, is defined by Formula (F.1):

$$U_f = \frac{L_f^{2D} - U_p\, b_p}{b_f} \tag{F.1}$$

where

U_f is the thermal transmittance of the frame section, in W/(m²·K);

L_f^{2D} is the thermal conductance of the section shown in Figure F.1, in W/(m·K);

U_p is the thermal transmittance of the central area of the panel, in W/(m²·K);

b_f is the projected width of the frame section (without protruding gaskets), in m;

b_p is the visible width of the panel, in m.

b_f is the larger of the projected widths seen from both sides. b_p is measured on the same side as b_f.

NOTE L^{2D} is calculated from the total heat flow rate per length through the section divided by the temperature difference between both adjacent environments; see ISO 10211.

F.2 Linear thermal transmittance of the junction with the glazing or opaque panel

The thermal transmittance of the glazing, U_g, is applicable to the central area of the glazing and does not include the effect of the spacer at the edge of the glazing. The thermal transmittance of the frame, U_f, is applicable in the absence of the glazing. The linear thermal transmittance, Ψ, describes the additional heat flow caused by the interaction of the frame and the glass edge, including the effect of the spacer.

To calculate the two-dimensional thermal coupling coefficient of the section consisting of the frame and the glazing including the spacer effect, the frame section with a projected frame width, b_f, and thermal transmittance U_f is completed by glazing with thermal transmittance U_g and length b_g; see Figure F.2. The value of the linear thermal transmittance, Ψ, is defined by Formula (F.2):

$$\Psi = L_\Psi^{2D} - U_f b_f - U_g b_g \tag{F.2}$$

where

Ψ is the linear thermal transmittance, in W/(m·K);

L_Ψ^{2D} is the thermal conductance of the section shown in Figure F.2, in W/(m·K);

U_f is the thermal transmittance of the frame section, in W/(m²·K);

U_g is the thermal transmittance of the central area of the glazing, in W/(m²·K);

b_f is the projected width of the frame section, in m;

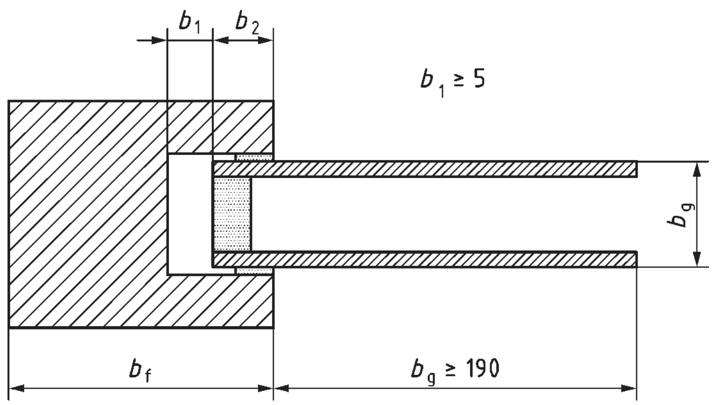
b_g is the visible width of the glazing, in m.

b_f is the larger of the projected widths as seen from both sides. b_g is measured on the same side as b_f.

The same procedure applies to frame sections for doors with opaque panels instead of glazing.

The same procedure, but without frame section, also applies to the linear thermal transmittance due to the combined effect of a glazing bar and glazing.

Dimensions in millimetres



Key

b_f width of the frame

b_p width of the panel

d_g thickness of the glazing

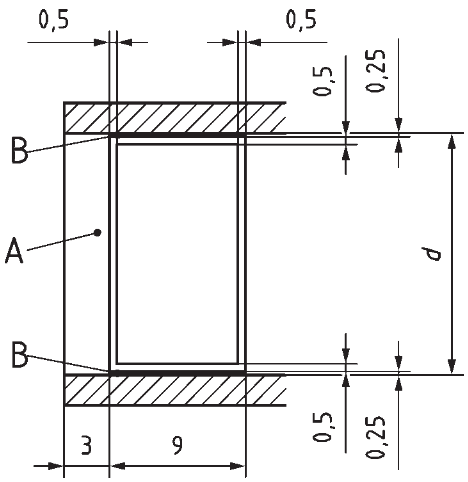
Figure F.2 — Schematic of profile section with glazing installed

NOTE A visible length of the panel or glass of 190 mm is sufficient for glazing with a thickness up to 60 mm. In other cases, the length needs to be increased; see ISO 10211.

To calculate Ψ-values for the combination of frame constructions with insulating glazing units (IGU) including metallic spacers when there is no detailed information about the geometry of the metal spacer, the following spacer shall be used.

The depth of the spacer *d* is the width of the cavity of the IGU reduced by 0,5 mm. This is because of a thickness of 0,25 mm of the inner sealant (butyl rubber) on either size of the spacer. For example if the width of the cavity in the IGU is 16 mm, the depth d of the spacer is 15,5 mm. The general geometry of the spacer and the integration in the IGU is shown in Figure F.3. If no other information is available the outer sealant should be polysulfide of thickness 3 mm.

Dimensions in millimetres



Key

A polysulfide

B butylene

Figure F.3 — Representative metal spacer incorporated in an IGU

Representative *Ψ*-values of thermally improved spacers can be established on the basis of representative profile sections and representative glass units. A detailed procedure is given in Reference [12].

Annex G
(normative)

General examples for the validation of calculation programs using the radiosity method for the treatment of cavities

G.1 Concentric cylinders

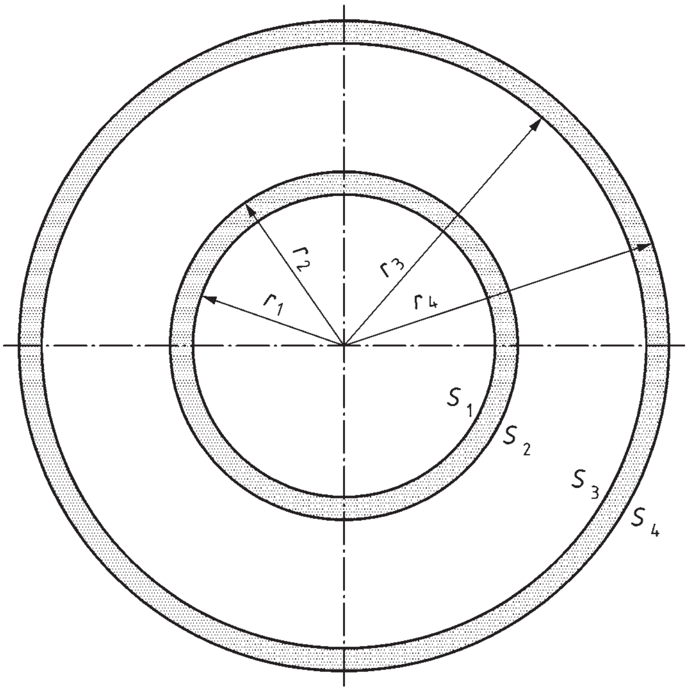


Figure G.1 — Vacuum cavity between two concentric cylinders

Figure G.1 shows two concentric cylinders with a vacuum between them. The dimensions are given in Table G.1.

The cylinders are perfect conductors (λ approximately ∞).

At the inner surface of the smaller cylinder (S_1) and at the outer surface of the larger cylinder (S_4), the surface temperatures specified in Table G.2 are applied.

The heat transfer between the outer surface of the smaller cylinder (S_2) and the inner surface of the larger cylinder (S_3) occurs by radiation only. The radiation heat flow is to be calculated by the calculation program for four variants of the surface emissivities of the surfaces S_2 and S_3 as given in Table G.3.

The difference (in relative terms) between the radiation heat flow from the calculation program to be validated and the analytically calculated radiation heat flow listed in Table G.4 shall be less than 3 %.

Table G.1 — Dimensions of cylinders

Key (Figure G.1)	Radius m
r_1	0,07
r_2	0,08
r_3	0,14
r_4	0,15

Table G.2 — Known surface temperatures

Surface	Temperature °C
S_1	20
S_4	0

Table G.3 — Surface emissivities

Variant	Emissivity of surface S_2	Emissivity of surface S_3
A	0,9	0,9
B	0,1	0,9
C	0,9	0,1
D	0,1	0,1

Table G.4 — Radiation heat flow from surface S_2 to surface S_3

Variant	Radiation heat flow W/m
A	44,12
B	5,15
C	8,29
D	3,42

G.2 Vacuum within a square cavity

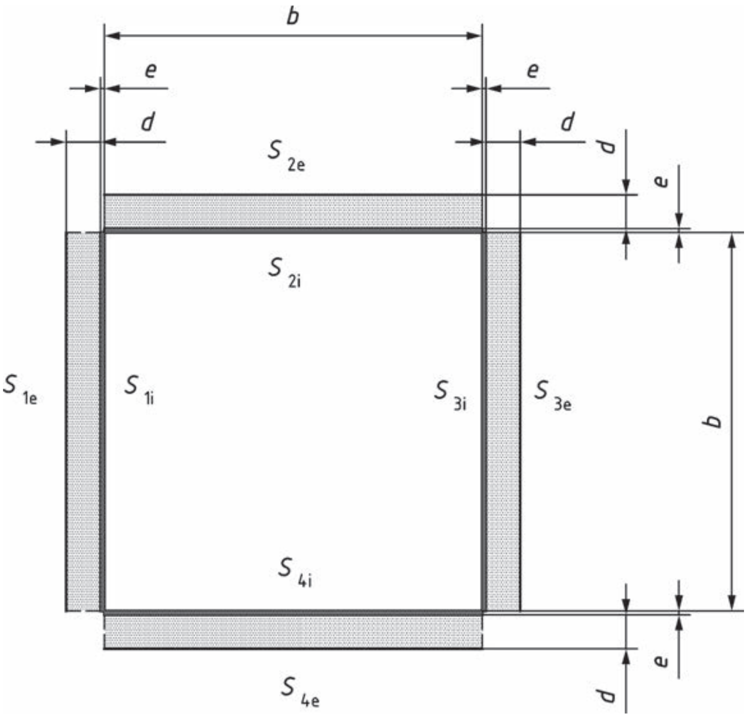


Figure G.2 — vacuum cavity surrounded by four walls

A vacuum cavity is surrounded by four walls. Dimensions are given in Table G.5.

Each wall has two layers. The thicker layer material (with thickness *d*) has a thermal conductivity of 1 W/(m·K). The thinner layer material (with thickness e) is a perfect conductor (λ approximately ∞). The emissivity of the thinner layer surface is 0,9. There is no thermal contact between the four thinner layers.

At the external wall surfaces, known environmental temperatures and surface heat transfer are applied as listed in Table G.6.

The heat exchange between the internal wall surfaces (S_{1i}, S_{2i}, S_{3i}, S_{4i}) occurs by radiation only.

The temperature distribution is to be calculated by the calculation program being validated. The difference between the central internal surface temperatures and the analytically calculated surface temperatures listed in Table G.7 shall be less than 0,2 °C.

Table G.5 — Dimensions

Key (Figure G.2)	Thickness m
d	0,10
e	0,01
b	1,00

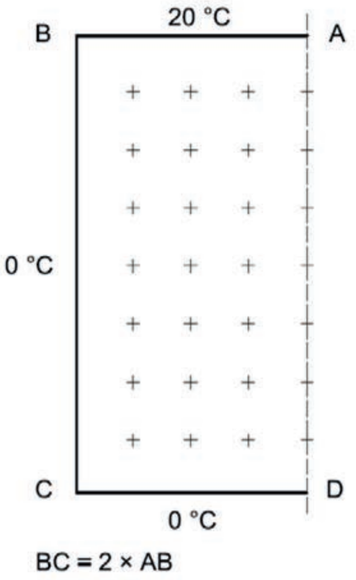
Table G.6 — External wall surface boundary conditions

Surface	Temperature °C	Surface resistance m²·K/W
S_{1e}	0	0,1
S_{2e}	5	0,1
S_{3e}	10	0,1
S_{4e}	20	0,1

Table G.7 — Internal surface temperatures

Surface	Temperature °C
S_{1i}	4,67
S_{2i}	7,25
S_{3i}	9,18
S_{4i}	13,89

G.3 Half square column with specified surface temperatures



Analytical solution at grid nodes (°C)			
9,7	13,4	14,7	15,1
5,3	8,6	10,3	10,8
3,2	5,6	7,0	7,5
2,0	3,6	4,7	5,0
1,3	2,3	3,0	3,2
0,7	1,4	1,8	1,9
0,3	0,6	0,8	0,9

Figure G.3 — Half square column with known surface temperatures: Data

The heat transfer through half a square column with known surface temperatures (Figure G.3) can be calculated analytically. The analytical solution at 28 points of an equidistant grid is given in the same figure. The difference between the temperatures calculated by the calculation program being validated and the temperatures listed shall not exceed 0,1 °C.

G.4 Air cavity

Dimensions in millimetres

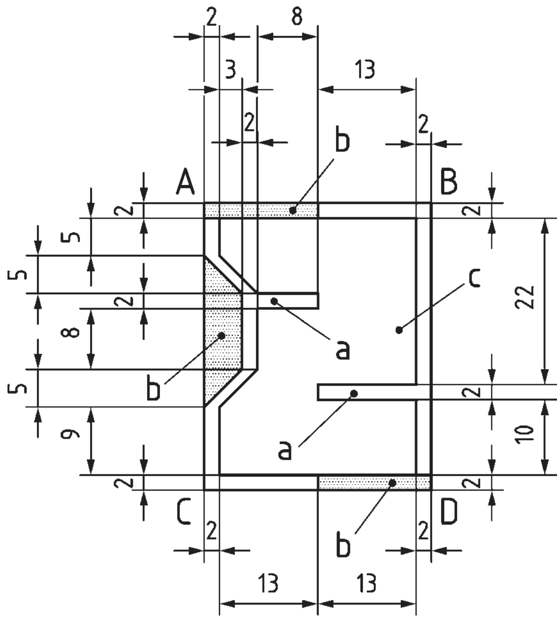


Figure G.4 — Air cavity surrounded by two materials

An air cavity (c) is surrounded by two materials (a and b), as shown in Figure G.4.

The thermal conductivity of material a is 0,3 W/(m·K). The thermal conductivity of material b is 0,001 W/(m·K). All material surfaces have emissivity 0,9.

Adjacent to surface AB there is an environment with temperature 20 °C and surface resistance 0,13 m^2·K/W.

Adjacent to surface CD there is environment with temperature 0 °C and surface resistance 0,04 m^2·K/W.

AC and BD are adiabatic boundaries.

The heat transfer through the materials and the cavity is by conduction, convection and radiation.

The difference (in relative terms) between the total heat flow from the calculation program being validated and that listed in Table G.8 shall be less than 3 %.

The cavity equivalent conduction direction, relative to the direction up the page and positive in clockwise direction, and the cavity equivalent conductivity are given in Table G.8 for information only.

Table G.8 — Calculated results

Cavity equivalent conduction direction	21,8°
Cavity equivalent conductivity	0,048 W/(m·K)
Total heat flow	0,826 W/K

Annex H
(normative)

Examples of window frames for the validation of calculation programs using the radiosity method for the treatment of cavities

H.1 General

This annex gives criteria for the validation of a calculation program. As stated in5.3, application of a program to frame sections in Figures H.1 to H.11 shall lead to results for L^{2D} differing by no more than 3 % from those given in Tables H.3 and H.4.

H.2 Figures

In Figures H.1 to H.11 the key shown in Tables H.1 and H.2 applies.

Table H.1 — Boundaries

Key	Surface resistance, R_s m2·K/W	Temperature, θ °C
A adiabatic	infinity	—
B external	see Annex E	0
C internal	see Annex E	20

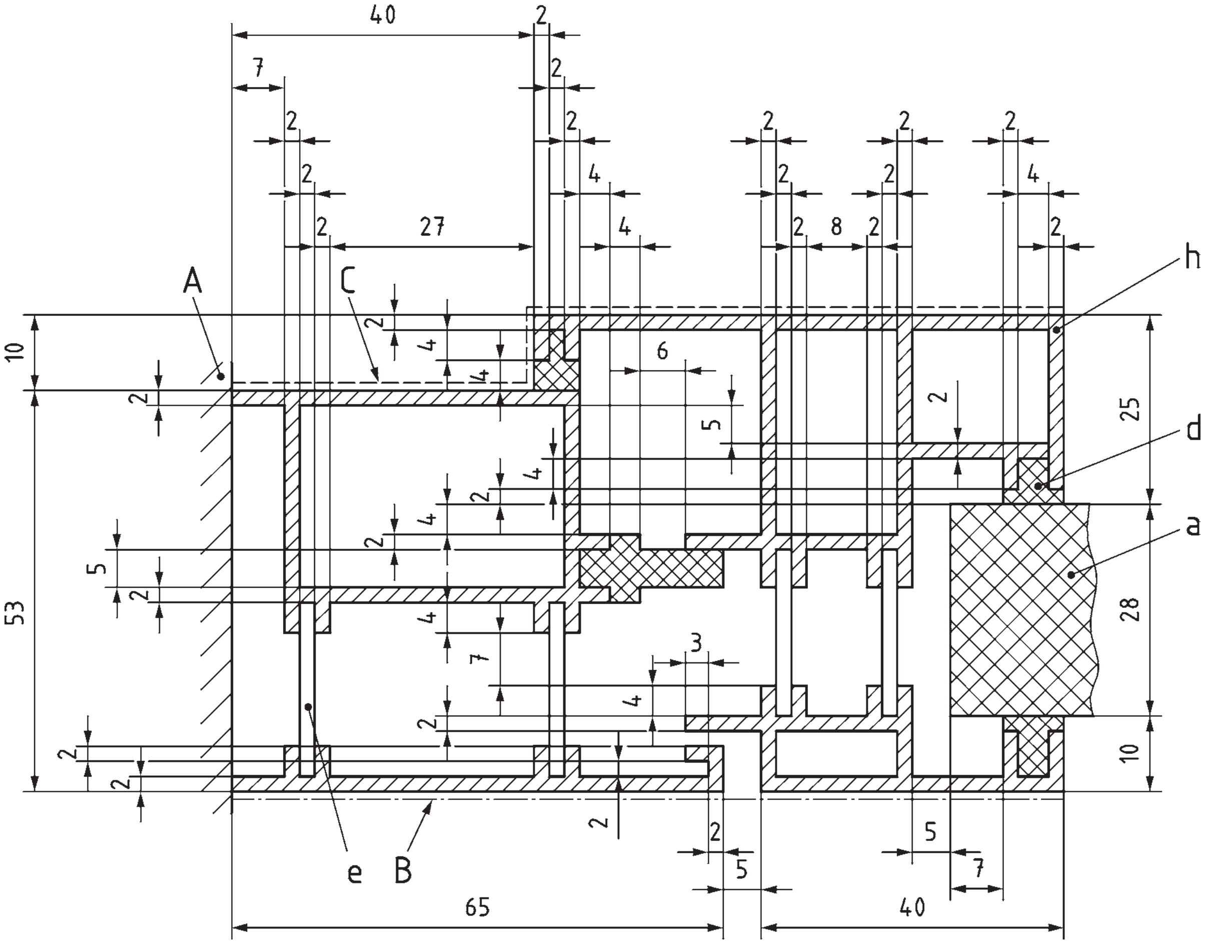
Table H.2 — Materials

Key	Material	Thermal conductivity, λ W/(m·K)
a	insulation panel	0,035
b	soft wood	0,13
c	PVC	0,17
d	EPDM	0,25
e	polyamide 6,6 with 25 % glass fibre	0,3
f	glass	1,0
g	steel	50
h	aluminium[a]	160
i	pile weather stripping (polyester mohair)	0,14
k	polyamide	0,25
l	PU (polyurethane), rigid	0,25
m	polysulfide	0,40
n	silica gel (desiccant)	0,13
o	gas filling	0,034[b]
p	polyisobutylene	0,20

[a] All surfaces have emissivity 0,9 except for Figure H.2.

[b] Equivalent thermal conductivity of the gas filling.

Dimensions in millimetres

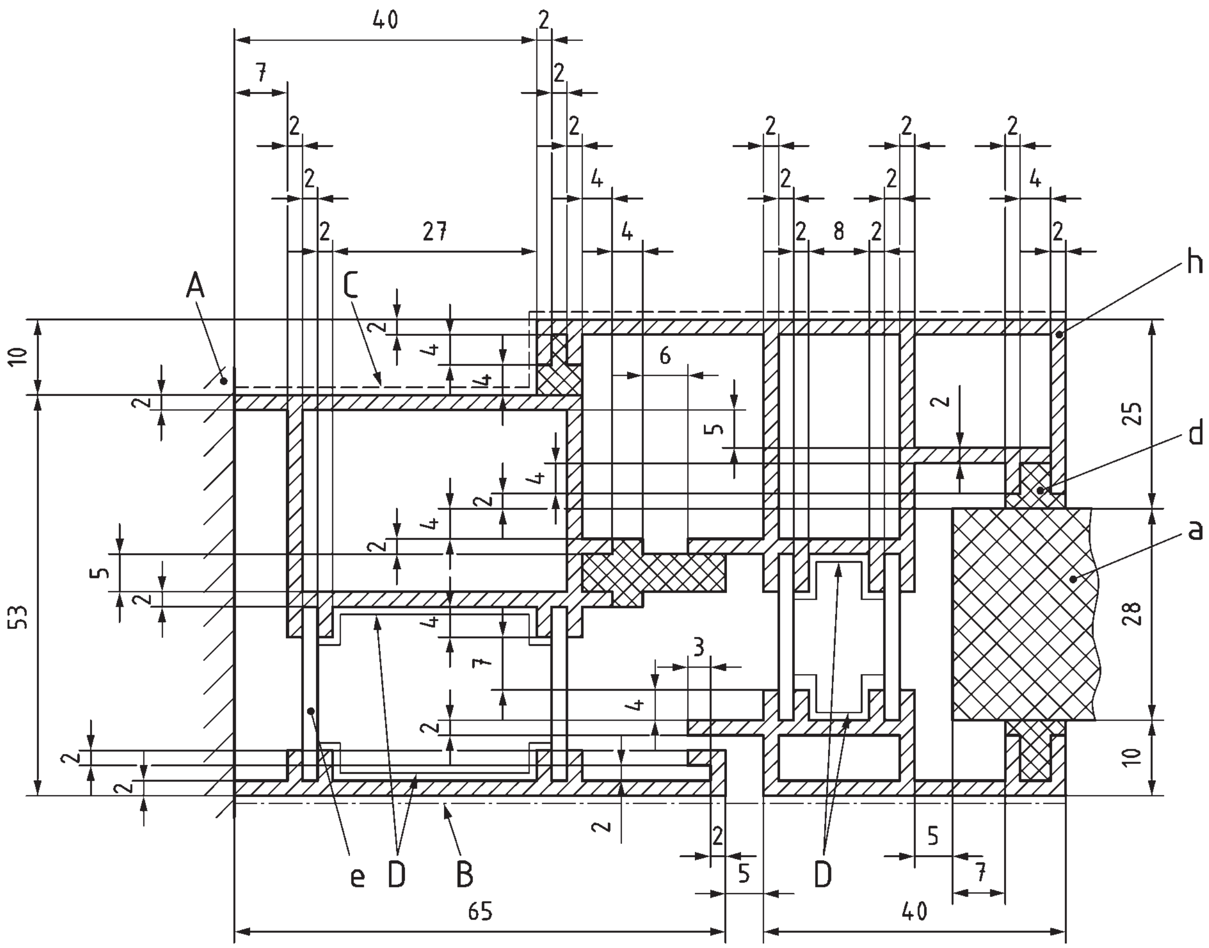


NOTE 1 The projected frame width, b_f, is 110 mm.

NOTE 2 Emissivity of all surfaces is equal to 0,9.

Figure H.1 — Aluminium frame section with thermal break and insulation panel

Dimensions in millimetres



Key

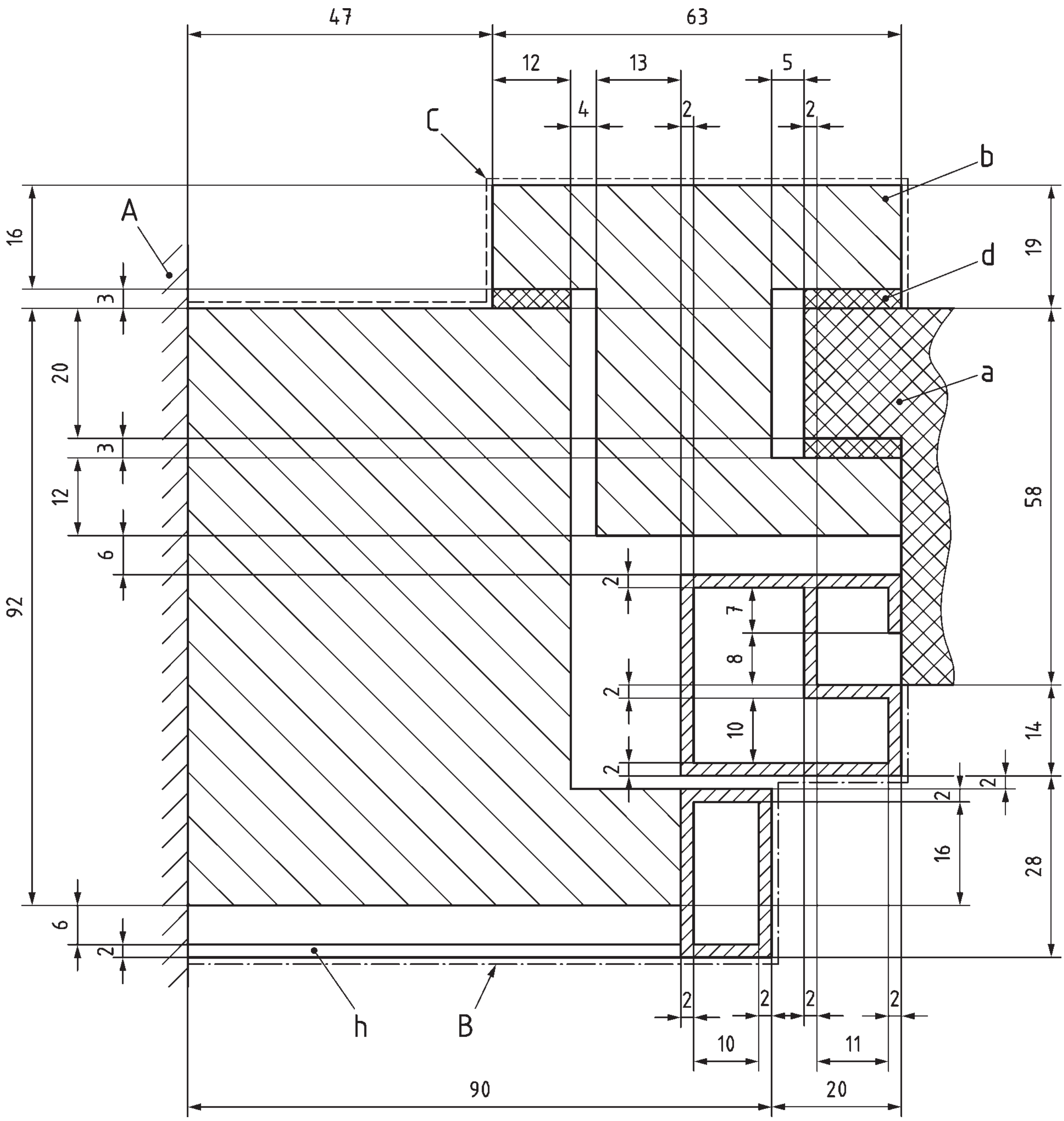
D emissivity 0,1

NOTE 1 The projected frame width, b_f, is 110 mm.

NOTE 2 Emissivity of specified surfaces is equal to 0,1; others, 0,9.

Figure H.2 — Aluminium frame section with thermal break and insulation panel

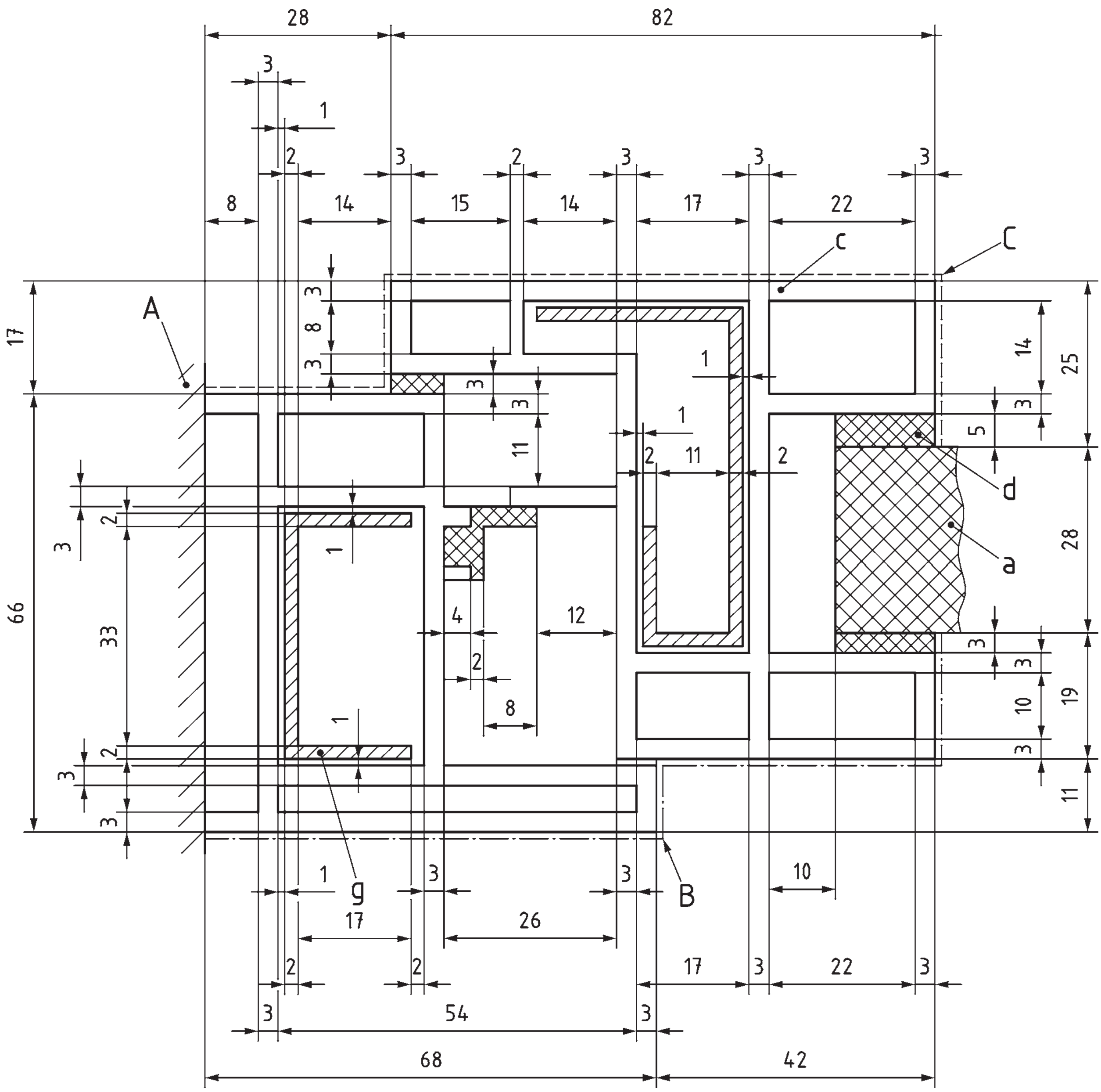
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure H.3 — Aluminium clad wood frame section and insulation panel

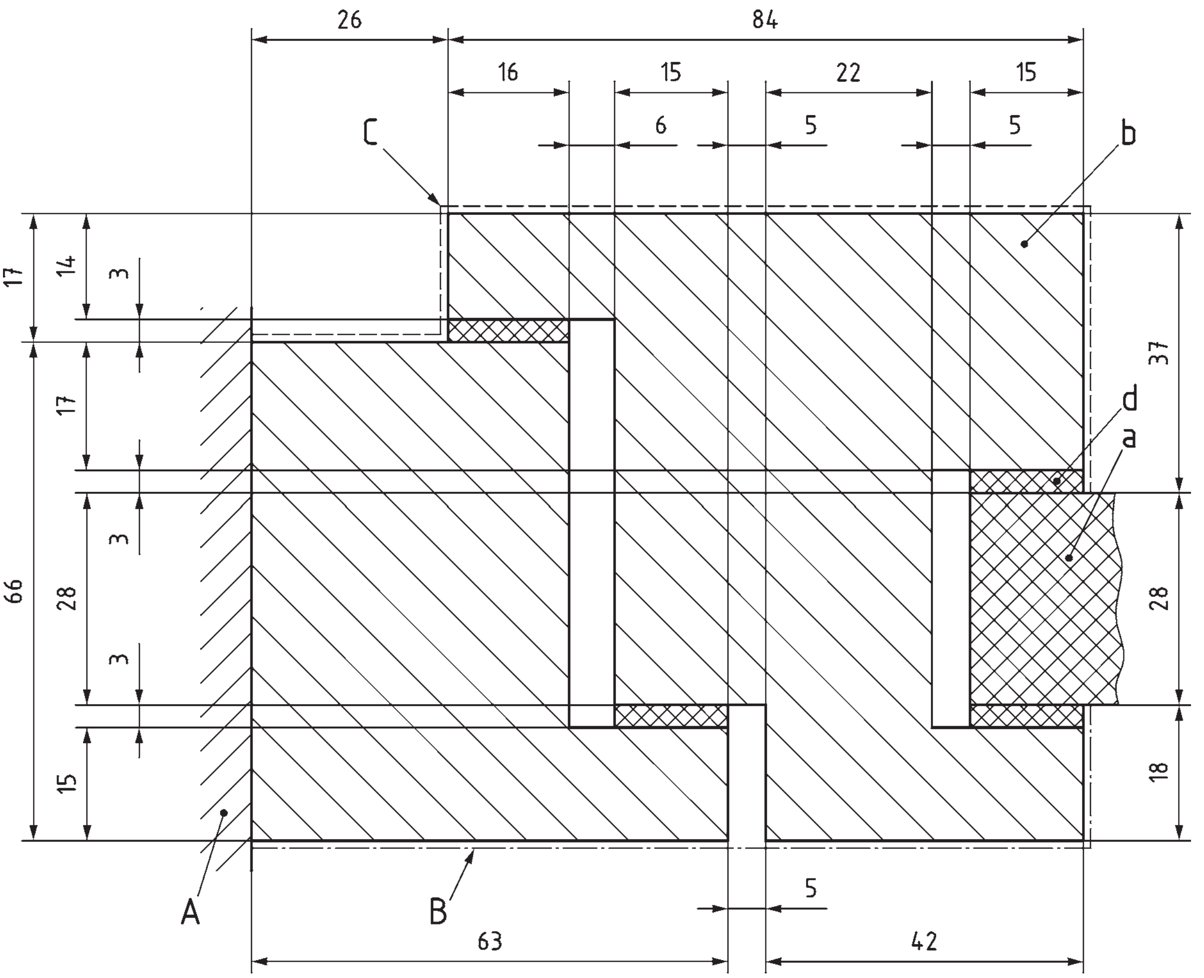
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure H.4 — PVC-frame section with steel reinforcement and insulation panel

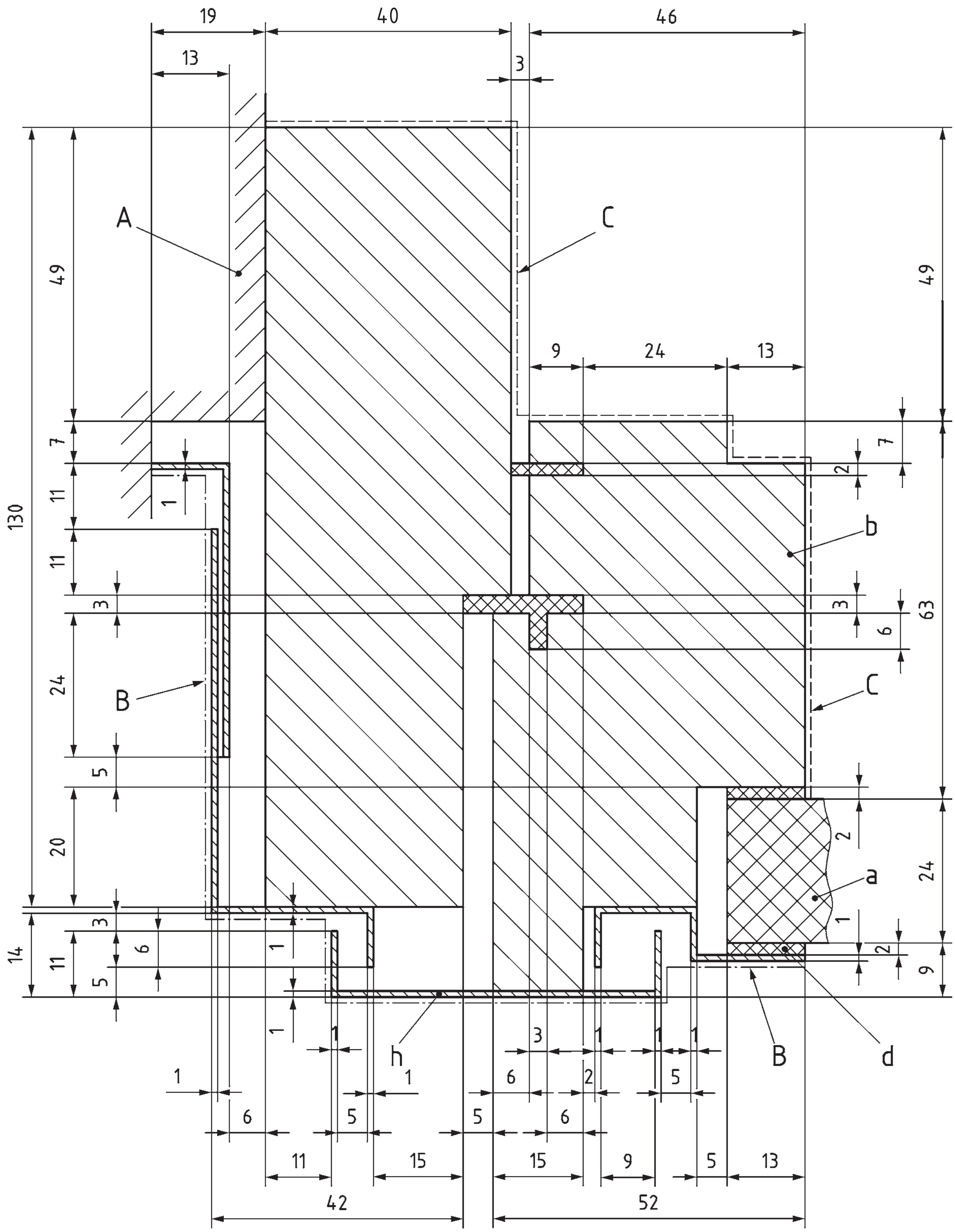
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure H.5 — Wood frame section and insulation panel

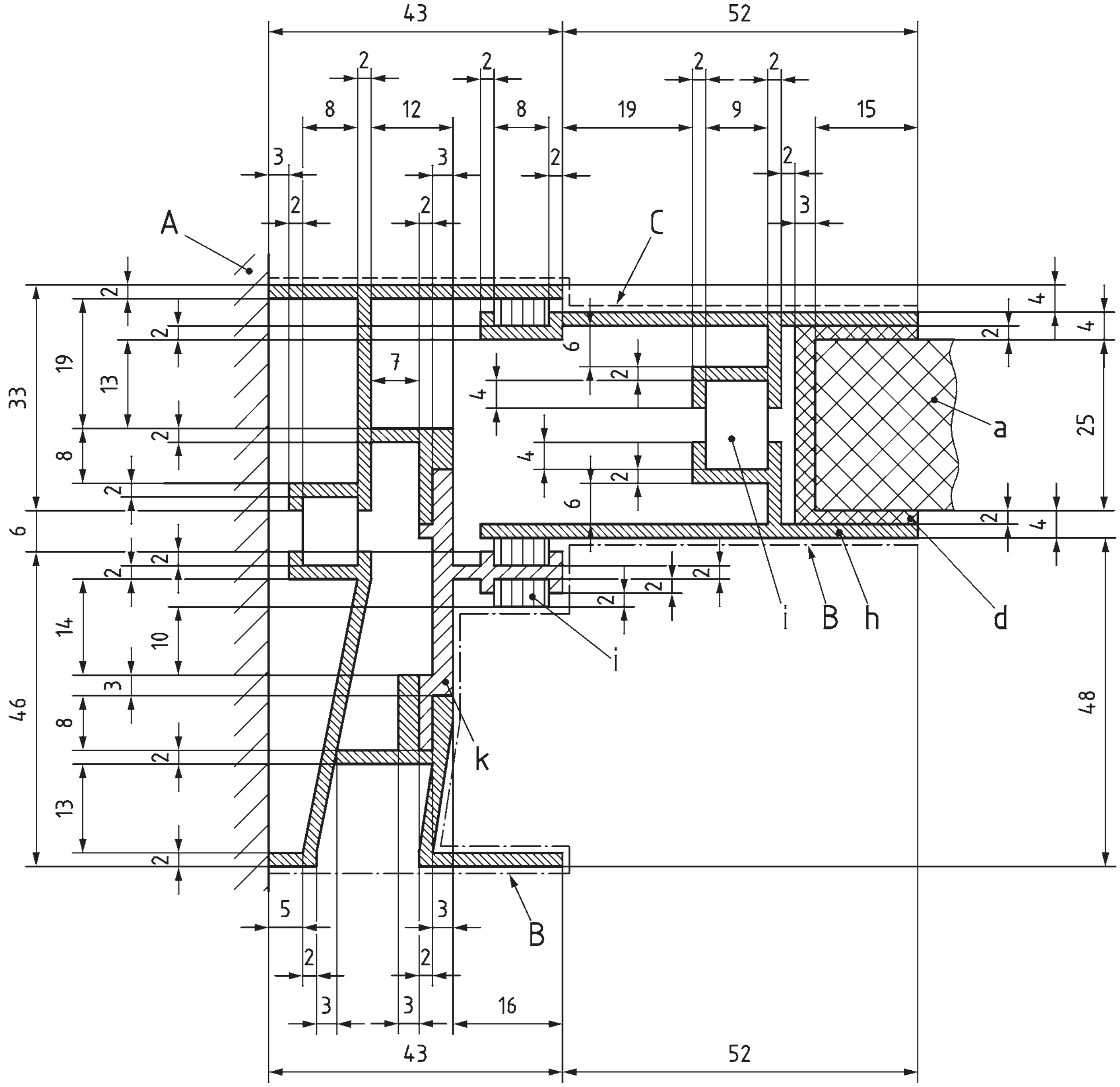
Dimensions in millimetres



NOTE The projected frame width, b_f, is 89 mm.

Figure H.6 — Roof window frame section and insulation panel

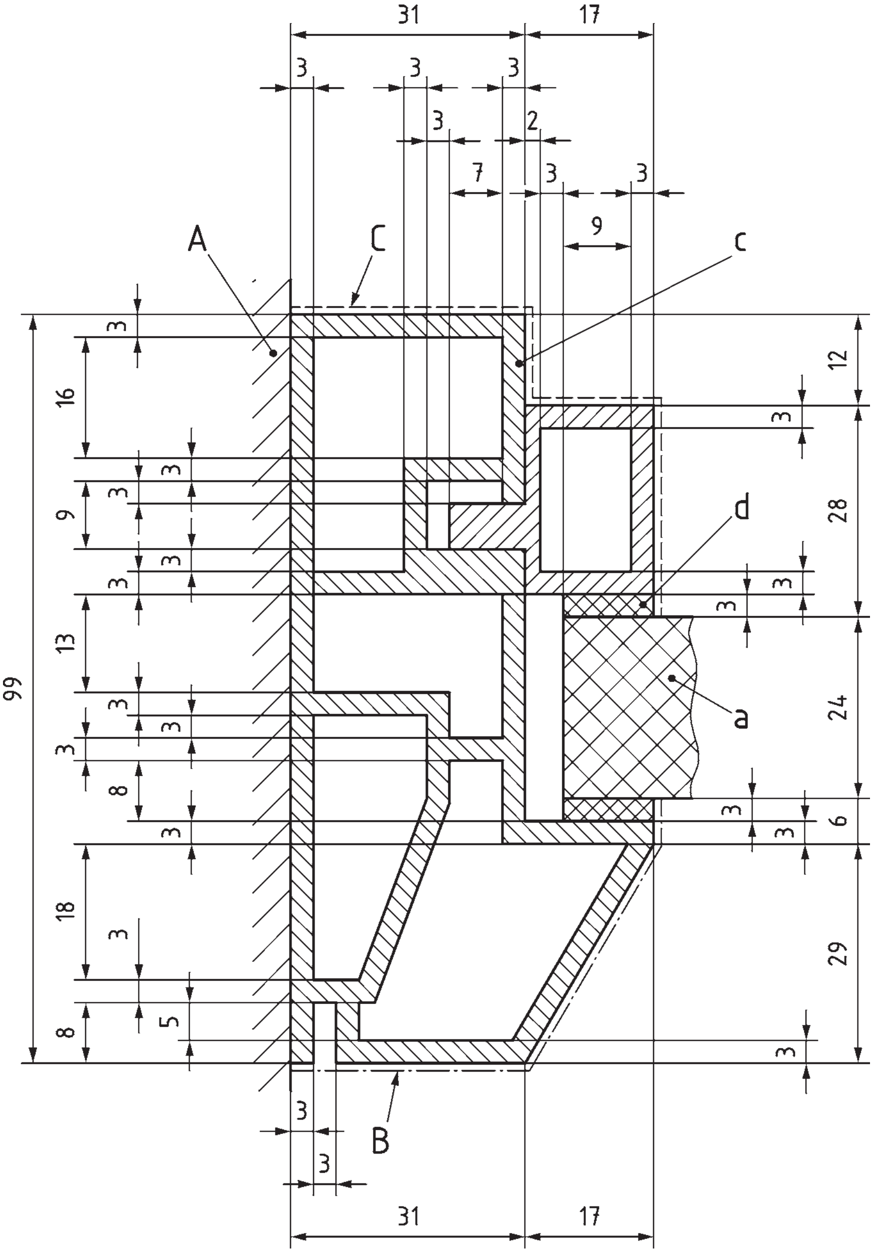
Dimensions in millimetres



NOTE The projected frame width, b_f, is 95 mm.

Figure H.7 — Sliding window frame section and insulation panel

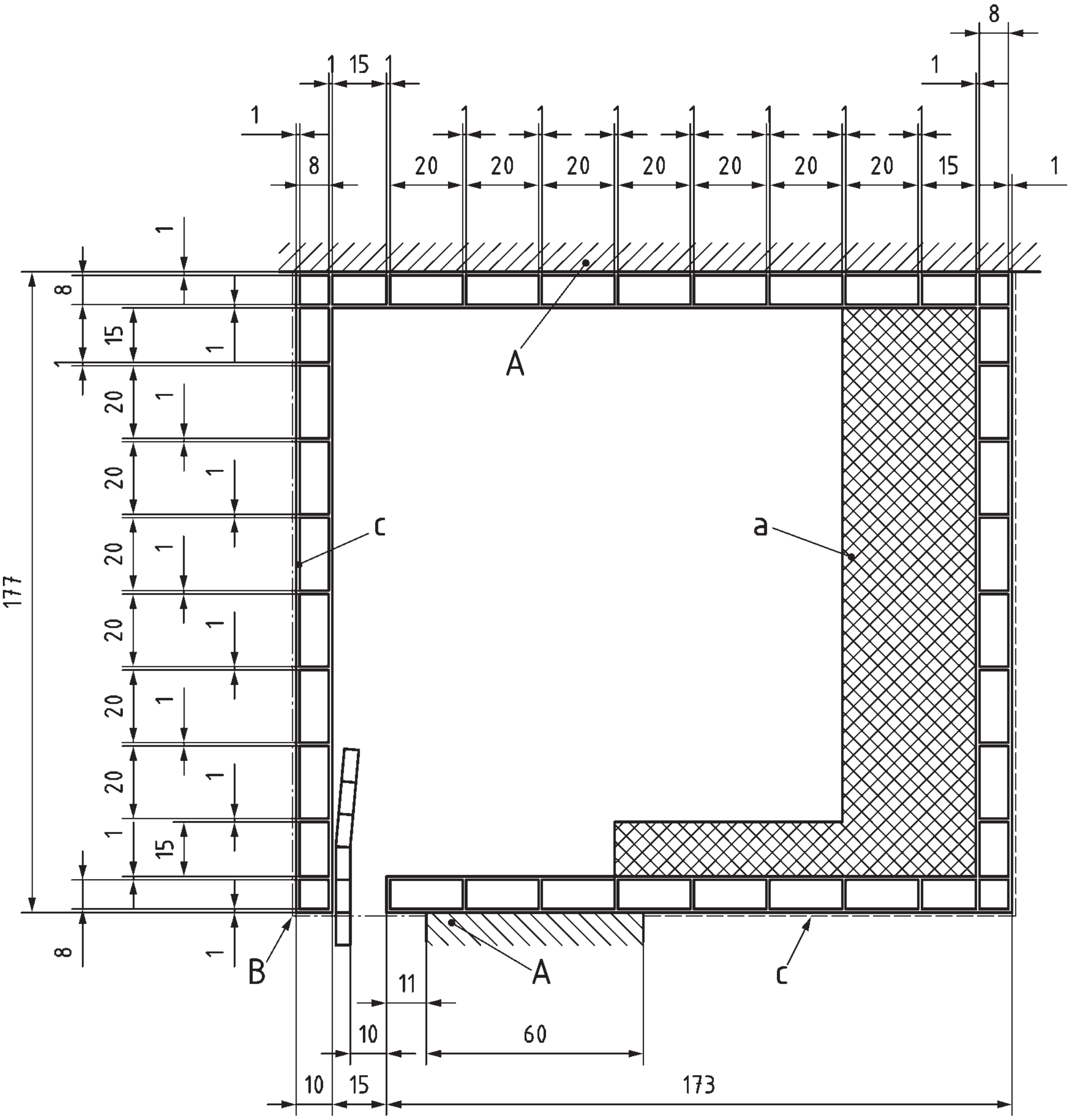
Dimensions in millimetres



NOTE The projected frame width, b_f, is 48 mm.

Figure H.8 — Fixed frame section and insulation panel

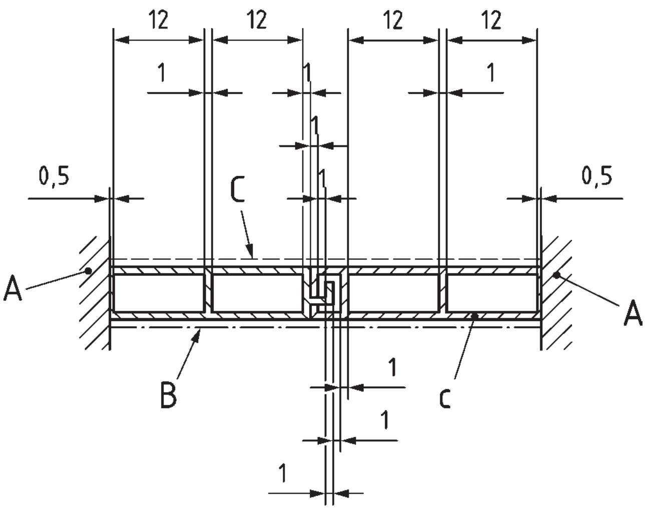
Dimensions in millimetres



NOTE The shutter box width, b_{sb}, is 177 mm.

Figure H.9 — Roller shutter box

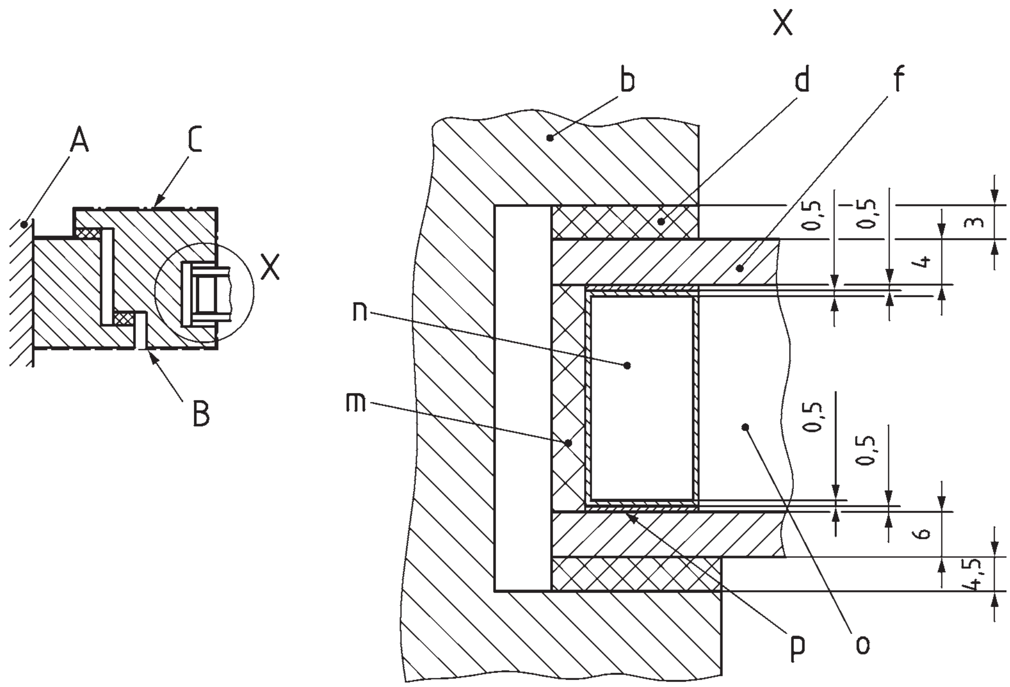
Dimensions in millimetres



NOTE The PVC shutter profile, *b*, is 57 mm.

Figure H.10 — PVC shutter profile

Dimensions in millimetres



NOTE See Figure H.5.

Figure H.11 — Example for the determination of a linear thermal transmittance of a wood frame section and of a glazing with U_g = 1,3 W/(m²·K) with a conventional glass edge system

To achieve a thermal transmittance of the insulating glass unit, U_g, of 1,3 W/(m²·K), the space of the insulating glass unit is filled with a solid material, marked “o”, with a thermal conductivity of 0,034 W/(m·K).

H.3 Results

Table H.3 — Calculated thermal conductance L^{2D} and thermal transmittance

Example	L^{2D} W/(m·K)	U_f W/(m2·K)
Figure H.1	0,539	3,11
Figure H.2	0,508	2,83
Figure H.3	0,252	1,35
Figure H.4	0,400	1,86
Figure H.5	0,344	1,34
Figure H.6	0,407	2,07
Figure H.7	0,637	4,44
Figure H.8	0,281	1,23
Figure H.9	0,188	1,06
Figure H.10	0,208	3,64
NOTE To avoid rounding errors the values are given to three significant figures.		

Table H.4 — Calculated thermal conductance, L_{Ψ}^{2D}, and linear thermal transmittance

Example	L_{Ψ}^{2D} (m·K)	Ψ W/(m·K)
Figure H.11	0,478	0,083

Annex I
(normative)

Examples of window frames for the validation of calculation programs using the single equivalent thermal conductivity method for the treatment of cavities

I.1 General

This annex gives criteria for the validation of a calculation program. As stated in 5.3, application of a program to frame sections in Figures I.1 to I.10 shall lead to results for L^{2D} differing by no more than 3 % from those given in Tables I.3 and I.4.

I.2 Figures

In Figures I.1 to I.10, the key shown in Tables I.1 and I.2 applies.

Table I.1 — Boundaries

Key	Surface resistance, R_s m²·K/W	Temperature, θ °C
A adiabatic	infinity	—
B external	see Annex E	0
C internal	see Annex E	20

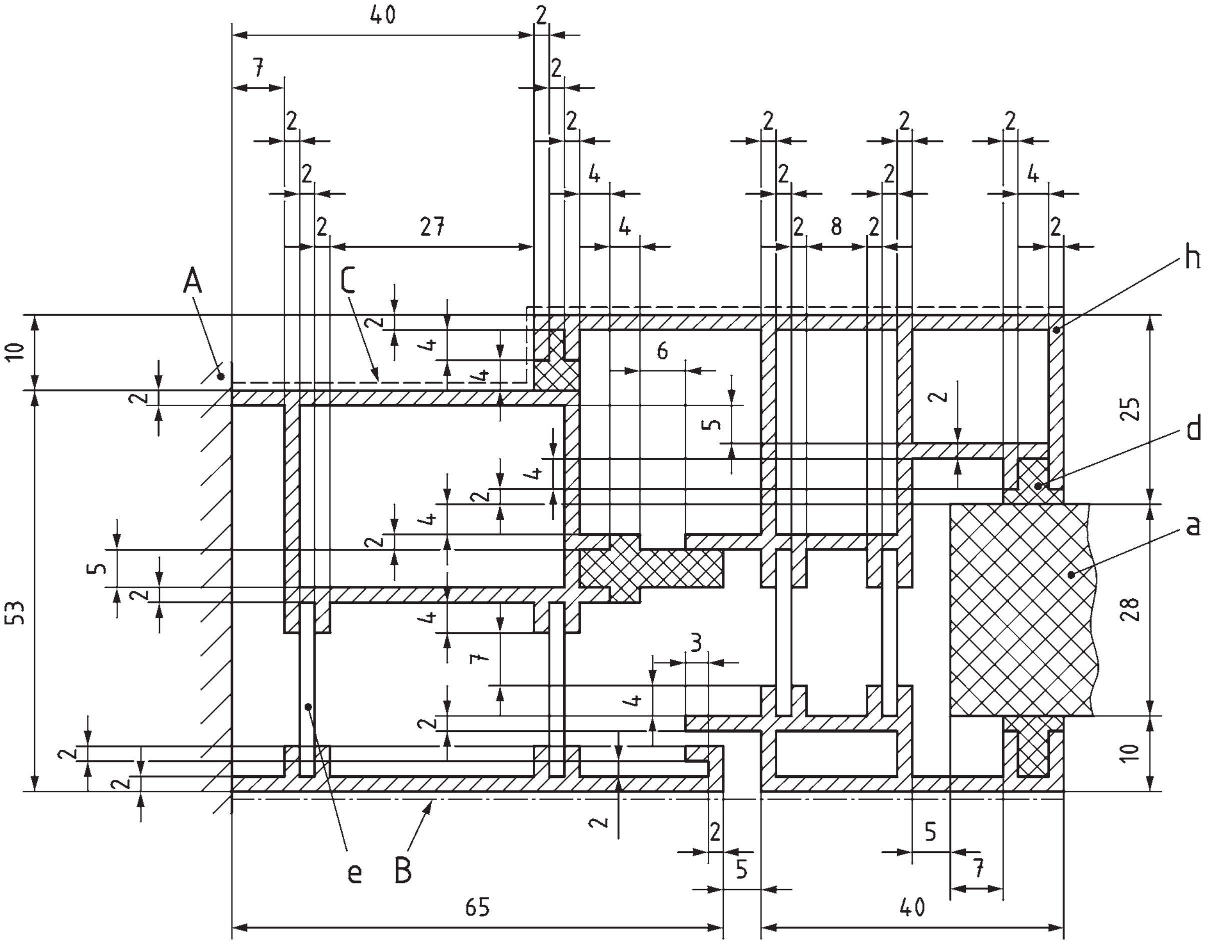
Table I.2 — Materials

Key	Material	Thermal conductivity, λ W/(m·K)
a	insulation panel	0,035
b	soft wood	0,13
c	PVC	0,17
d	EPDM	0,25
e	polyamide 6,6 with 25 % glass fibre	0,3
f	glass	1,0
g	steel	50
h	aluminium[a]	160
i	pile weather stripping (polyester mohair)	0,14
k	polyamide	0,25
l	PU (polyurethane), rigid	0,25
m	polysulfide	0,40
n	silica gel (desiccant)	0,13
o	gas filling	0,034[b]
p	polyisobutylene	0,20

[a] All surfaces have emissivity 0,9.

[b] Equivalent thermal conductivity of the gas filling.

Dimensions in millimetres

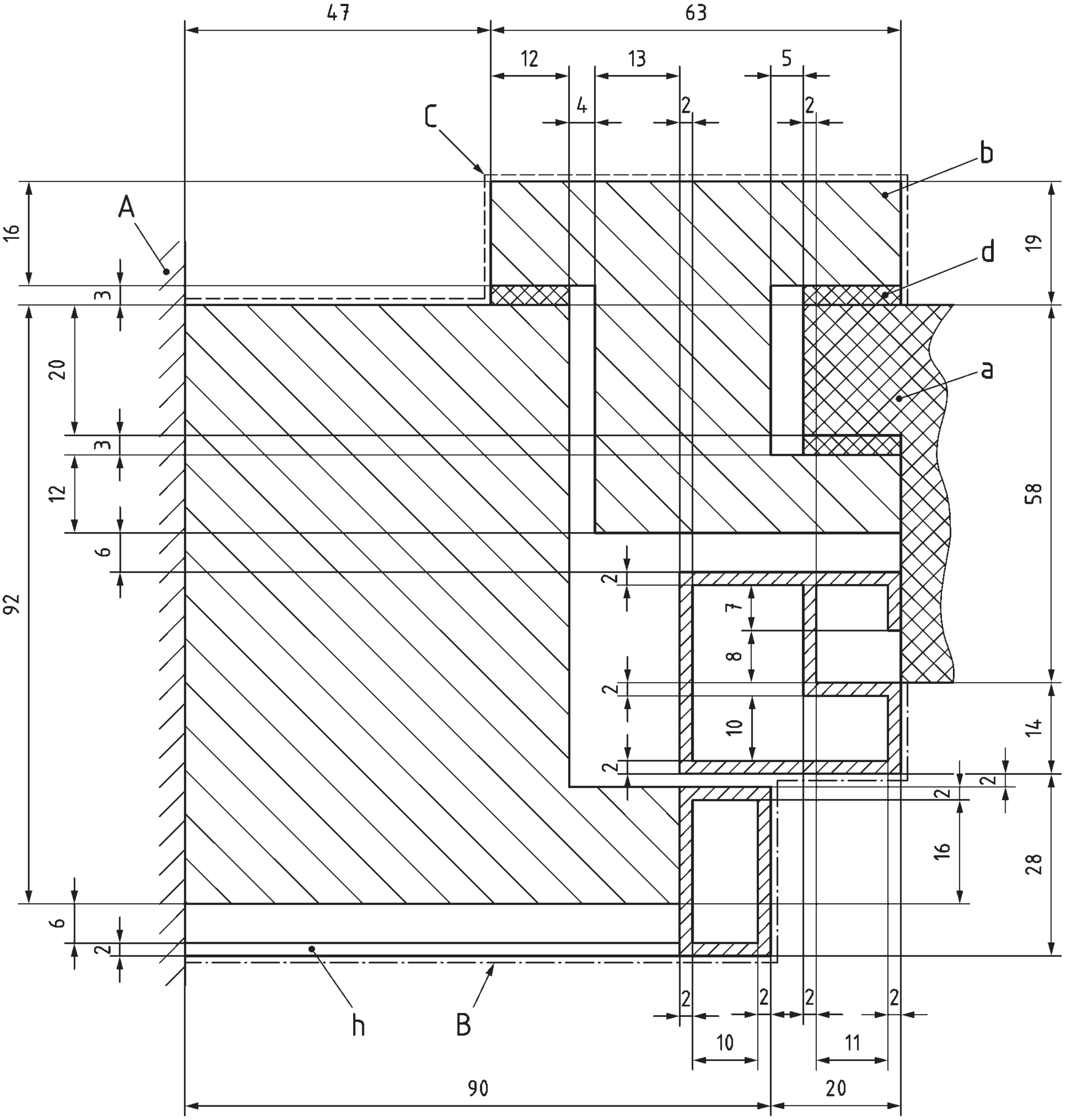


NOTE 1 The projected frame width, b_f, is 110 mm.

NOTE 2 Emissivity of all surfaces is equal to 0,9.

Figure I.1 — Aluminium frame section with thermal break and insulation panel

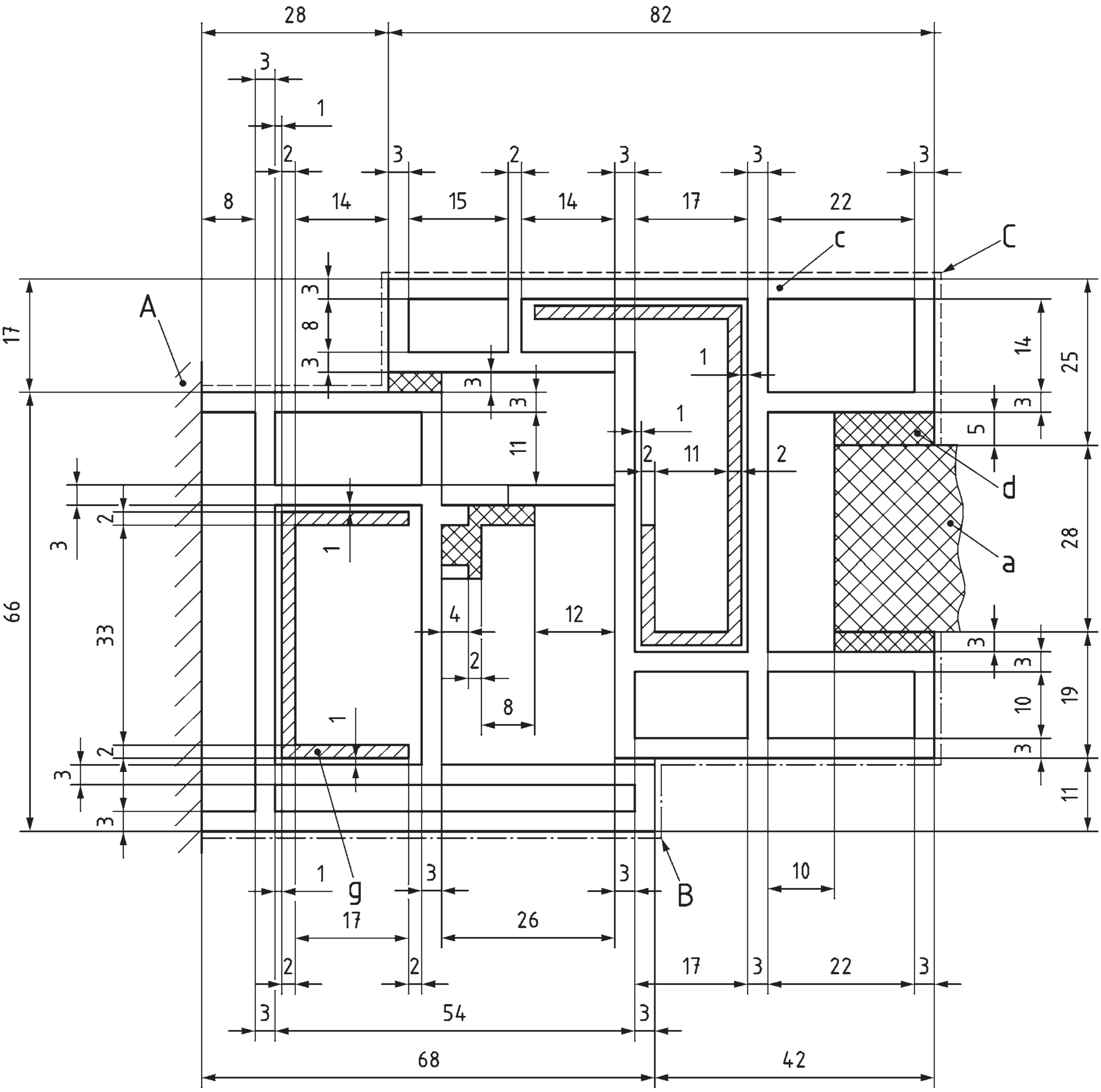
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure I.2 — Aluminium clad wood frame section and insulation panel

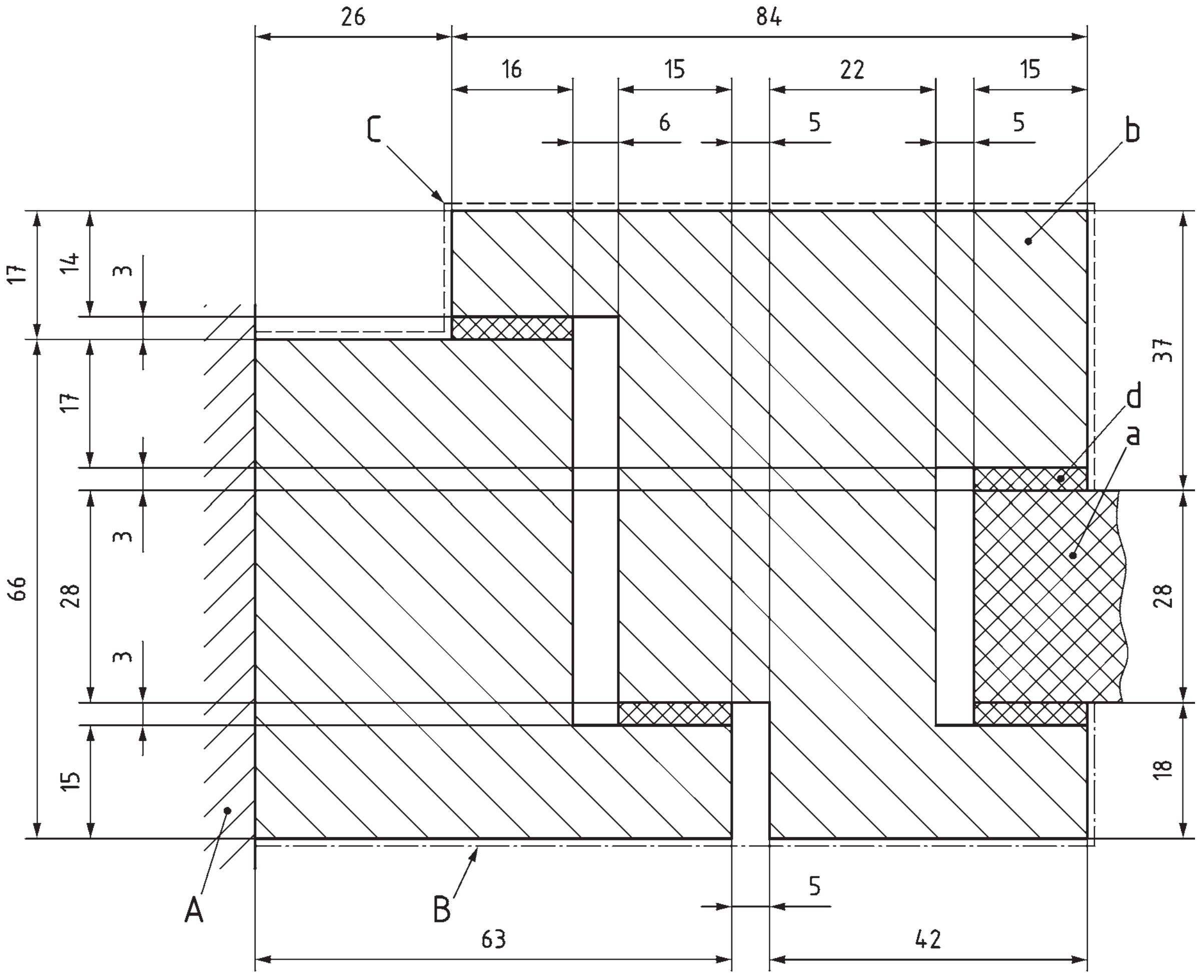
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure I.3 — PVC-frame section with steel reinforcement and insulation panel

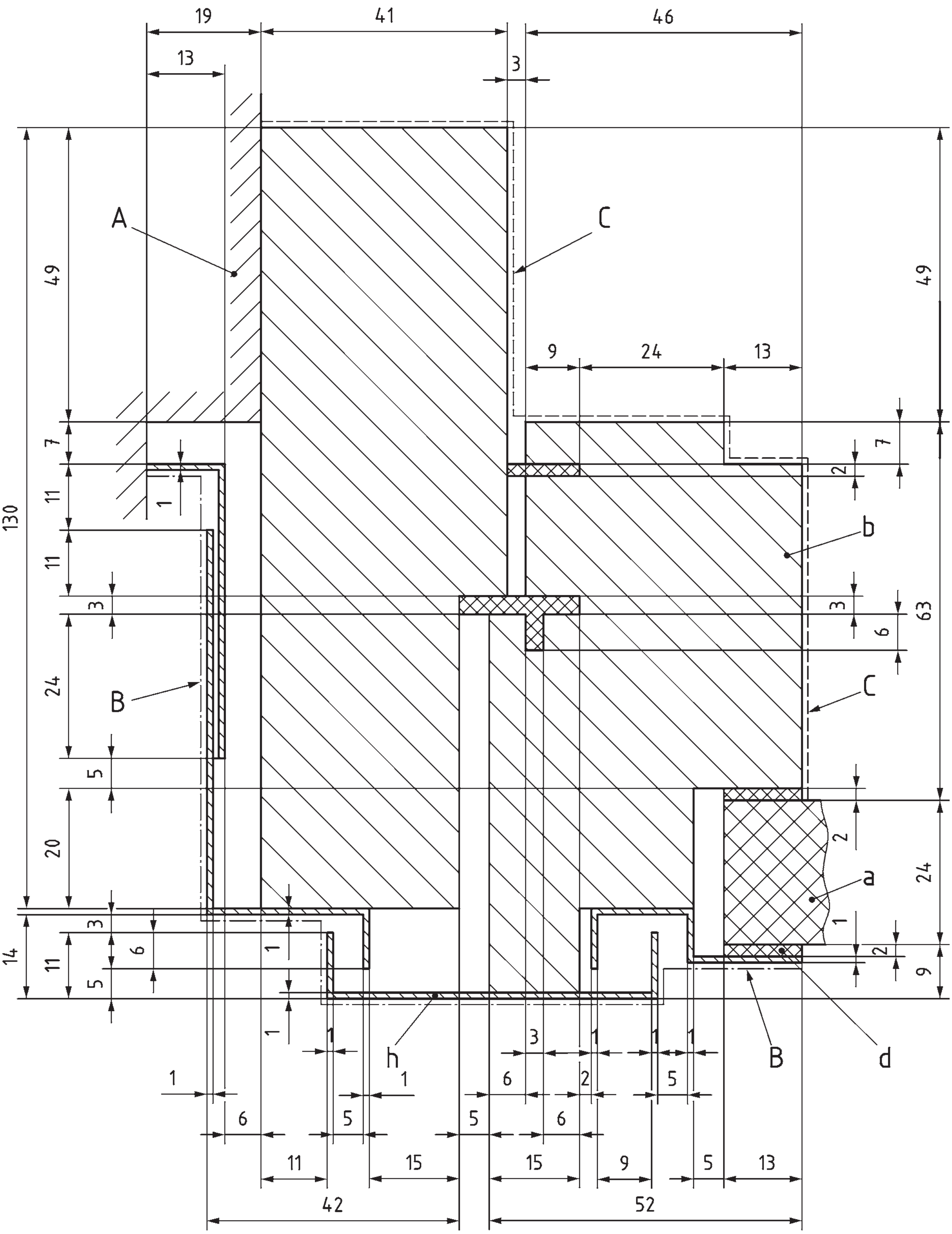
Dimensions in millimetres



NOTE The projected frame width, b_f, is 110 mm.

Figure I.4 — Wood frame section and insulation panel

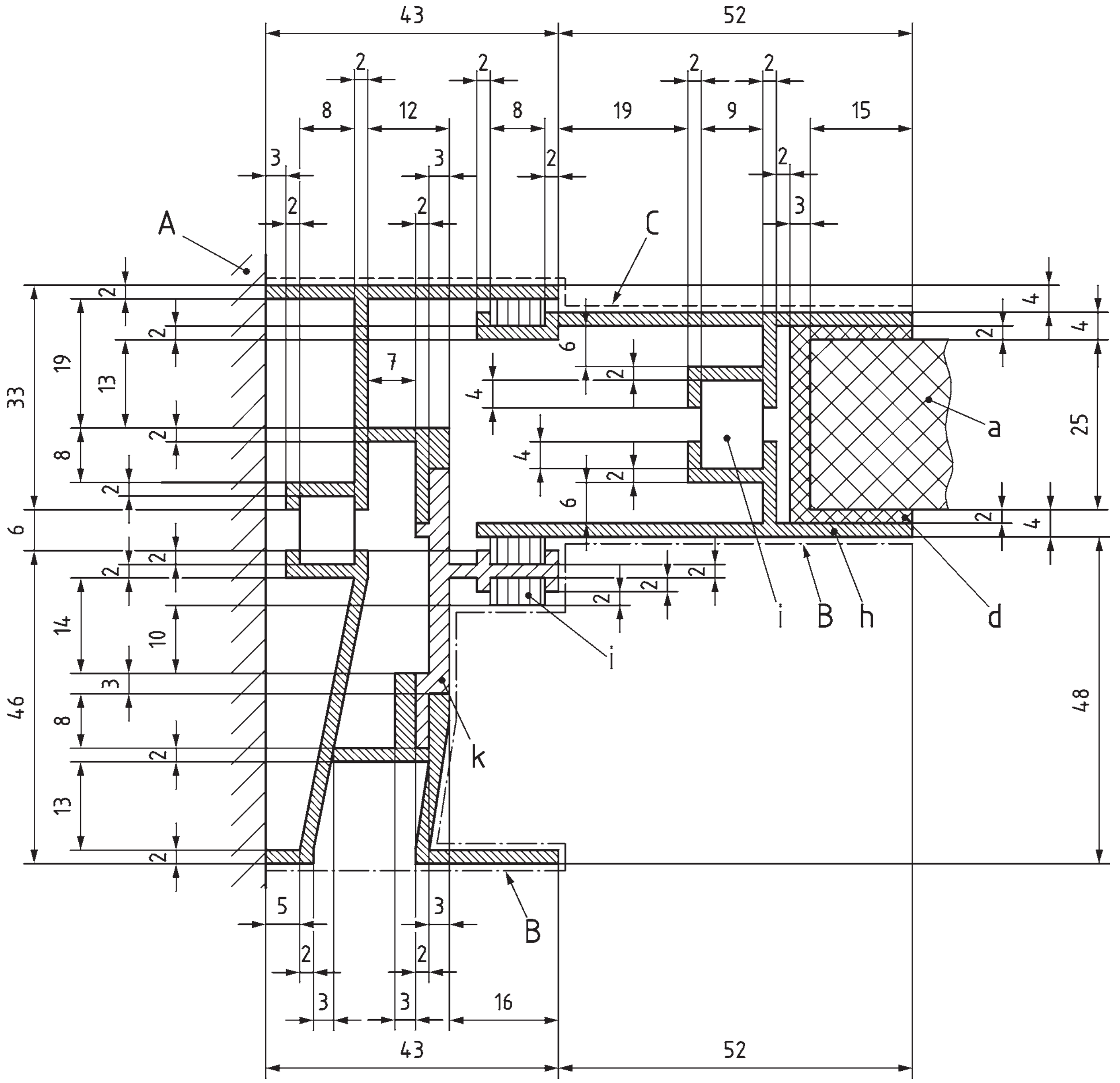
Dimensions in millimetres



NOTE The projected frame width, b_f, is 89 mm.

Figure I.5 — Roof window frame section and insulation panel

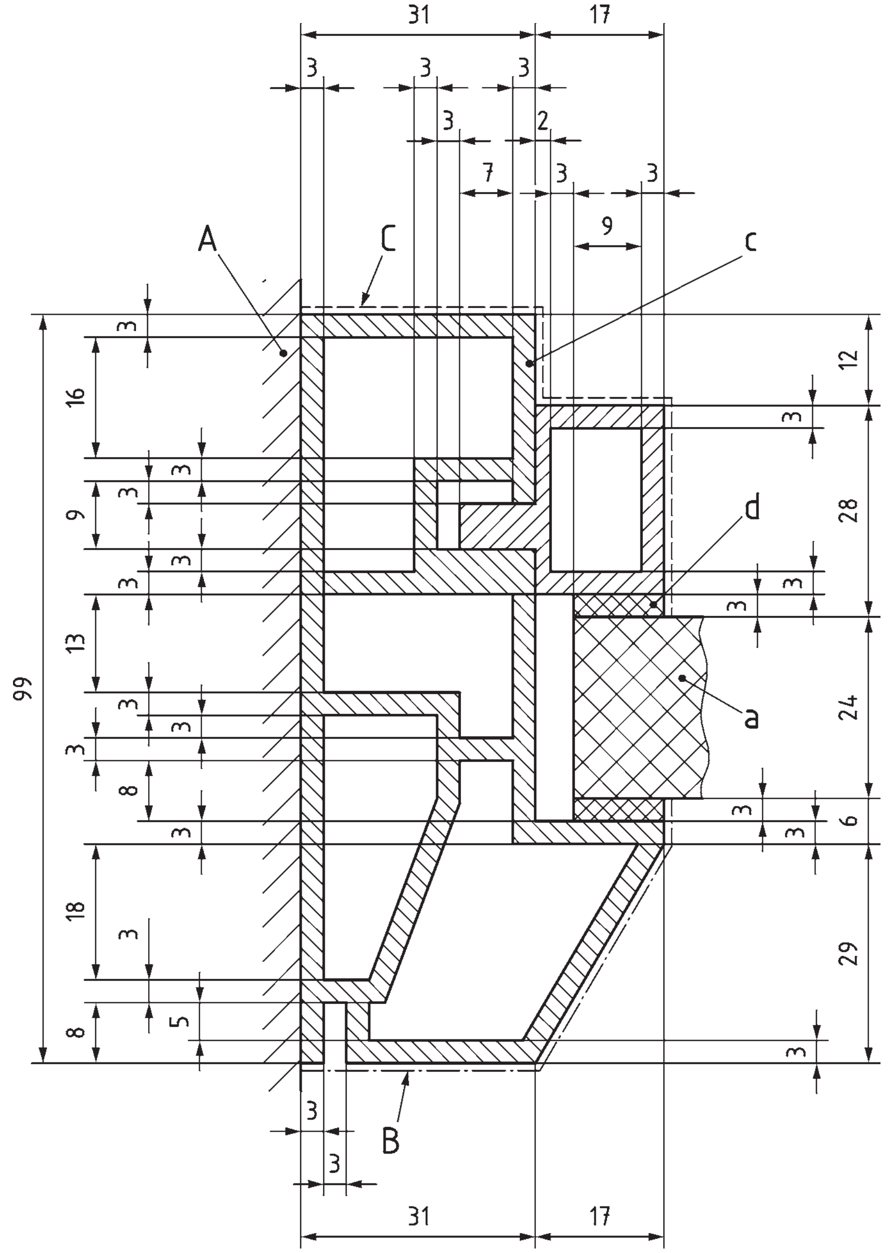
Dimensions in millimetres



NOTE The projected frame width, b_f, is 95 mm.

Figure I.6 — Sliding window frame section and insulation panel

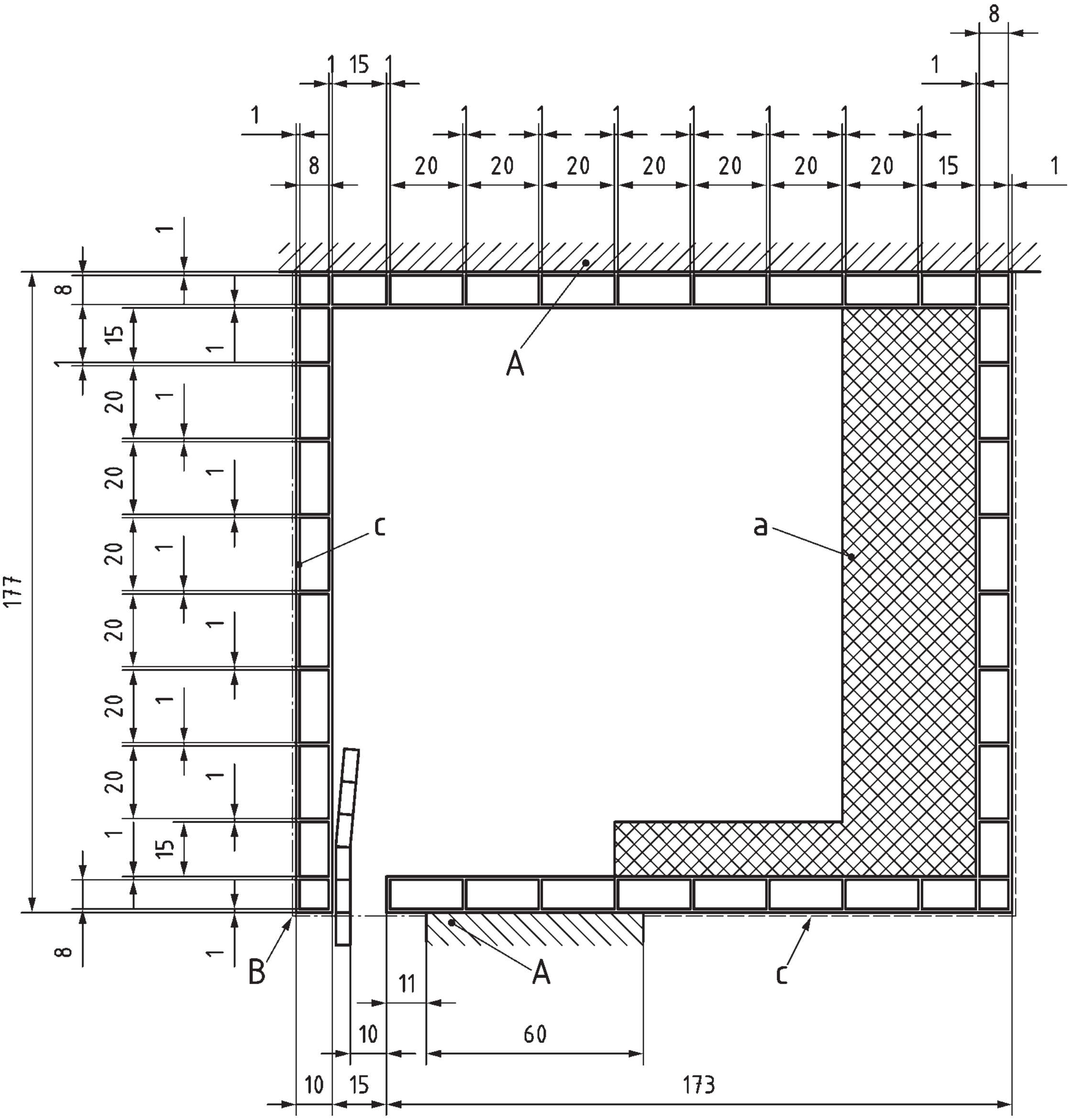
Dimensions in millimetres



NOTE The projected frame width, b_f, is 48 mm.

Figure I.7 — Fixed frame section and insulation panel

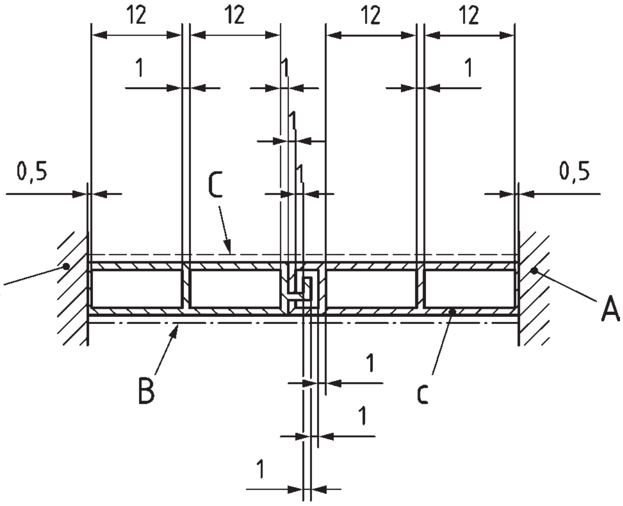
Dimensions in millimetres



NOTE The shutter box width, b_{sb}, is 177 mm.

Figure I.8 — Roller shutter box

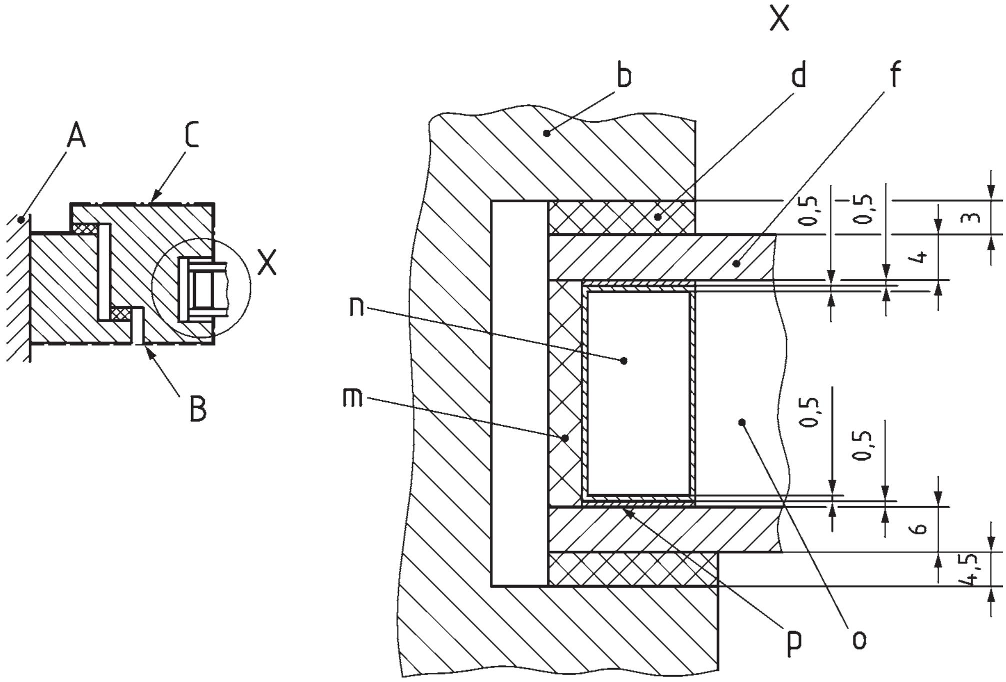
Dimensions in millimetres



NOTE The PVC shutter profile, *b*, is 57 mm.

Figure I.9 — PVC shutter profile

Dimensions in millimetres



NOTE See Figure H.5.

Figure I.10 — Example for the determination of a linear thermal transmittance of a wood frame section and of a glazing with U_g = 1,3 W/(m²·K) with a conventional glass edge system

To achieve a thermal transmittance of the insulating glass unit, U_g, of 1,3 W/(m²·K), the space of the insulating glass unit is filled with a solid material, marked “o”, with a thermal conductivity of 0,034 W/(m·K).

I.3 Results

Table I.3 — Calculated thermal conductance, L^{2D}, and thermal transmittance

Example	L^{2D} W/(m·K)	U_f W/(m²·K)
Figure I.1	0,550 (0,007)	3,22 (0,06)
Figure I.2	0,263 (0,001)	1,44 (0,03)
Figure I.3	0,424 (0,006)	2,07 (0,06)
Figure I.4	0,346 (0,001)	1,36 (0,01)
Figure I.5	0,408 (0,007)	2,08 (0,08)
Figure I.6	0,659 (0,008)	4,67 (0,09)
Figure I.7	0,285 (0,002)	1,31 (0,03)
Figure I.8	0,181 (0,003)	1,05 (0,02)
Figure I.9	0,207 (0,001)	3,64 (0,01)
NOTE To avoid rounding errors the values are given to three significant figures.		

Table I.4 — Calculated thermal conductance, L_{Ψ}^{2D}, and linear thermal transmittance

Example	L_{Ψ}^{2D} (m·K)	Ψ W/(m·K)
Figure I.10	0,481 (0,004)	0,084 (0,004)

The bracketed data in Tables I.3 and I.4 are standard deviations from a round-robin calculation of nine institutions from Europe and North America (June 2000).

Annex J
(normative)

Wood species listed in Annex D

Botanical name Dénomination botanique Botanischer Name	Code Code Kurzzeichen	English name	Dénomination française	Deutscher Name
Abies alba	ABAL	silver fir	sapin blanc	Tanne, Weißtanne
Afzelia spp.	AFXX	Afzelia	doussié	Afzelia
Calophyllum spp.	CLXX	Bintangor	bintangor	Bintangor
Entandrophragma cylindricum	ENCY	sapele	sapelli	Sapelli
Entandrophragma utile	ENUT	utile	sipo	Sipo
Eucalyptus delegatensis *Eucalyptus obliqua* *Eucalyptus regnans*	EUXX	“Tasmanian oak“	« chêne de Tasmanie »	„Tasmanian oak“
Eucalyptus globulus	EUGL	southern blue gum	eucalyptus bleu	Blue gum, Globulus
Eucalyptus saligna *Eucalyptus grandis* *Eucalyptus urophylla* *Eucalyptus uro-grandis*	EUSL EUGR EUUP EUUG	saligna gum eucalyptus	eucalyptus saligna eucalyptus	Sidney blue gum Eukalyptus
Heritiera spp.	HEXM	mengkulang	mengkulang	Mengkulang
Heritiera utiliz *Heritiera densiflora*	HEXN	niangon	niangon	Niangon
Intsia bijuga *Intsia palembanica*	INXX	merbau	merbau	Merbau
Khaya spp.	KHXX	African mahogany	Acajou d’afrique	Khaya (Mahagoni)
Larix spp. *Larix decidua* *Larix x eurolepis* *Larix gmelina* *Larix oocarpa*	LAXX LADC LAER LAGM LAOC	Larch European larch Dunkeld larch Siberian larch Western larch	mélèze mélèze d’Europe mélèze de Dunkeld mélèze de Sibérie western larch	Lärche Lärche Dunkeld-Lärche Sibirische Lärche Kanadische Lärche
Milicia excels *Milicia regia*	MIXX	iroko	iroko	Iroko, Kambala
Ocotea rubra	OCRB	red louro	louro vermelho	Louro vermelho

[a] The species Swietenia macrophylla (SWMC, American Mahogany) is listed as “endangered species” under the CITES agreement. The availability may therefore be restricted.

NOTE 1 The codes and names were taken from EN 13556, wherever possible.

NOTE 2 The abbreviation spp. (species pluralis) means that such an assortment may comprise (similar) timbers originating from several botanical species.

NOTE 3 Names in quotation marks (“ ”) are commercial names which have become common by long-standing use. Such denominations are, however, not correct from the botanical point of view.

Botanical name **Dénomination botanique** **Botanischer Name**	**Code** **Code** **Kurzzeichen**	**English name**	**Dénomination française**	**Deutscher Name**
Picea abies	PCAB	Norway spruce	épicéa	Fichte
Picea glauca	PCGL	white spruce	eastern spruce	Western white spruce, Weißfichte
Picea sitchensis	PCST	Sitka spruce	Sitka spruce	Sitka spruce, Sitkaf-ichte
Parashorea spp.	PHMG	meranti gerutu	gerutu	Gerutu, Heavy White Seraya
Parashorea spp.	PHWS	white seraya	white seraya	Light white seraya
Pometia pinnata	PMPN	taun	kasai	Kasai, Matoa
Pinus contorta	PNCN	lodgepole pine	pin de Murray	Lodgepole Pine, Dre-hkiefer
Pinus sylvestris	PNSY	Scots pine	pin sylvestre	Kiefer, Föhre
Pseudotsuga menziesii	PSMN	Oregon pine “Douglas fir”	Douglas (pin d’Oregon)	Oregon Pine, Douglasie
Quercus spp.	QCXA QCXE	American White Oak European oak	Chêne blanc d’Améri-que chêne	Amerikanische Weißeiche Eiche
Robinia pseudoacacia	ROPS	robinia (Black locust)	robinier	Robinie
Shorea spp.	SHDR	dark red meranti	dark red meranti	Dark red meranti
Shorea spp.	SHLR	light red meranti	light red meranti	Light red meranti
Swietenia macrophylla	SWMC	American mahogany[a]	Acajou d’Amérique[a]	Amerikanisches Ma-hagoni[a]
Tectona grandis	TEGR	teak	teck	Teak
Terminalia ivorensis	TMIV	idigbo	framiré	Framiré
Tieghemella africana *Tieghemella heckelii*	TGAF TGHC	makoré makoré	douka makoré	Makoré Makoré
Thuja plicata	THPL	“western red cedar”	“western red cedar”	„western red cedar”, Rotzeder
Tsuga heterophylla	TSHT	western hemlock	western hemlock	Western hemlock, Hemlock

[a] The species Swietenia macrophylla (SWMC, American Mahogany) is listed as “endangered species” under the CITES agreement. The availability may therefore be restricted.

NOTE 1 The codes and names were taken from EN 13556, wherever possible.

NOTE 2 The abbreviation spp. (species pluralis) means that such an assortment may comprise (similar) timbers originating from several botanical species.

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[3] ISO 12631, *Thermal performance of curtain walling — Calculation of thermal transmittance*

[4] ISO 15099, *Thermal performance of windows, doors and shading devices — Detailed calculations*

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